GLIDING AND ADVANCED SOARING

"*The winds and waves are always on the side of the ablest navigators.*"

EDWARD GIBBON

GLIDING AND ADVANCED SOARING

A. C. Douglas

With CONTRIBUTIONS by

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and a FOREWORD by

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TO

DAVID BRUNT, F.R.S.

WHO HAS DONE SO

MUCH FOR

BRITISH GLIDING

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CONTENTS

Chapter			*Page*
1.	History of Soaring Flight	(A.E.S.)	11
2.	Launching Methods	(A.C.D.)	33
3.	Instructional Methods	,,	52
4.	Club Operation	,,	88
5.	Meteorology	(A.E.S.)	111
6.	Cross Country Flying	(P.A.W.)	173
7.	Altitude Flying	,,	192
8.	Some Geological Influences	(A.C.D.)	212
9.	Review of Sailplanes	,,	219
10.	Layout	,,	243
11.	Tools, Materials, Jigs, Building and Repairs	(A.C.D.)	268
12.	Instruments, Releases, Trailers, Retrieving Cars	(A.C.D.)	285
13.	Some Well-known Hill Sites	,,	300
	Appendices		312

With 94 Figures, 40 Diagrams, and
2 Sketch Maps in colour

FOREWORD

ALL who have read Mrs. Ann Douglas's *Cloud Reading for Pilots* will especially welcome this further contribution from her pen to knowledgable soaring literature. Broadly speaking, it would appear that only recently has the Science and Art of Soaring Flight been adequately and tastefully dealt with; earlier efforts tended to be too technical or too highly coloured and piecemeal, rather than a straightforward and objective digging-down to the roots and mainsprings of the art.

Although it is some time now since her first book appeared, I still think that it has not received the attention and recognition that it should have done, inasmuch as she was the first to produce a book dealing solely with the air and its structure with special reference to human flight. In other words, to our shame, it may have appeared before its time. In all previous Gliding books the Machine and the Man had been the fundamental basis of the theme.

Then for the first time, Mrs. Douglas directed our attention to the air itself as the fount and mainspring of future study, investigation and discovery; showing how the sub-conscious, if not the conscious mind of the early pioneers had on balance tended that way. I for one believe she was right, and I believe the next ten years' experience will conclusively prove it. The internal combustion engine had blinded our eyes and dulled our hands to the subtle but dynamic forces with which our atmosphere is packed for our good or ill as we choose, and in proportion to our knowledge.

It is obviously necessary to have designed and built the finest aircraft and evolved the finest piloting technique, but when this had been done and well done, the time had arrived for us to become fully air conscious, with the will and knowledge to look for, recognise, use, or avoid, and in the case of thermal "break-aways" over and adjoining aerodromes, etc., *to chart*, the forces which have been continuously liberated in our atmosphere since the beginning of time. In other words, we must "KNOW OUR ELEMENT" in a much more intimate and knowledgable way than it has been generally known or thought necessary to know up to the present, if we are going to complete its conquest and extract that indefinable pleasure which accrues to those who succeed in harnessing natural forces and using them to achieve their objectives.

All Gliding people know that this is no idle dream or theory, but is actually taking place at the present time in a small way by a very few around several aerodromes and soaring grounds, with prospects of extension when high-efficiency soaring craft are available. The fundamental truth which is now apparent is that in each given wind direction, on any and every site, there are definite but limited areas where up-current or down-draughts can be regularly expected whenever conditions are right for thermal activity; and that these areas are *constant in each given wind direction*, and can therefore be charted. It was in this manner that eleven "C" certificates were taken off the flat Walsall Aerodrome in 1945 during two A.T.C. courses there. Once these spots are located, all that remains to be done is to find the periodicity of the breakaways each day and the flights timed accordingly, which is now a common practice at the more advanced clubs.

Therefore, this book which traces the evolution of the human desire and aspiration to fly, and which indicates the simplest methods of enabling man to get into the air, and which at the same time indicates the direction in which he is to look for further progress, is particularly welcome at the present time when the individual urge to fly is being cramped and starved through the aftermath of war and general official apathy; many problems with which this book deals are as yet generally unrecognised officially as existing or of any practical importance. It unfortunately appears to be true that only those relatively few who have themselves played the gentle lift of an evening thermal, or fought and held their first big and active day thermal, or again have been seized and whirled upwards by the full force of the storm cloud, or travelled up and down the length of a cloud street, can fully appreciate that there is a problem to solve and many further lessons to be wrenched from nature. Therefore, I think that the greatest contribution that the individual can make at the present time is to quietly continue with his or her soaring at every favourable moment, collecting, recording and charting data which can then be pieced together and used for the general furtherance of the Art and the general safety of air travel.

These conditions, however, presuppose the existence in this Country of suitable machines in sufficient quantities to supply the tools for wrestling with this intricate problem, and here,

unfortunately, is the greatest obstacle with which the British Gliding movement is faced. Stripped of its own machines by its own patriotic action during the War, nothing officially has been done so far to replace this precious equipment. Without the freeing of supplies and allotting of factory space, we gliding people can do nothing. It is, therefore, fairly and squarely a Government responsibility to give us the material for the tools so that we can do the job. Never was a movement more deserving of consideration and help than this movement which was born with the hand of every man against it and the finger of derision pointed in its direction. Landowners, vested interests, farmers, physical obstacles of every variety, and weather, transport and finance, all had to be overcome before the brain and hand of man were free to design and build and fly machines of the necessary strength and layout to cope with this intricate and, in the early days, obscure science; alone, unaided until 1937, gliding people did it. Accordingly, they should have earned respect and consideration.

This new book, by pioneers of British Club Gliding, should be generally welcomed both by the old hand and the newcomer, to whom it will be found of equal interest and value, inasmuch as it shows clearly whence and how we have come and to whence we are directing our steps.

C. ESPIN HARDWICK

The authors would like to express their thanks to the Royal Aeronautical Society for permission to include figures 1–7; to D. F. Greig for figures 17 and 76; to C. H. W. Edmonds for figure 90; to F. W. M. Ruck for diagram 39; to the Air Division Gliding Club for figures 6, 9 and 70; and to the editors of *Sailplane* and the *Newcastle Journal* for figures 16, 17, 21 and 19 respectively.

Chapter 1

HISTORY OF SOARING FLIGHT

THE birds, who inspired the human race with the idea of flying, have two ways of keeping up in the air. Either the wings are flapped up and down, or else they are held rigid while the bird sails along without apparent effort. For birds do not invariably glide down to earth when resting on their wings; at times they *soar:* that is, they maintain height or even climb upwards.

It might be thought that, through all the centuries before mechanical power became available, soaring would be the method of choice for any would-be aviator. Then why was it not done until the twentieth century?

The story which follows will show that, before human soaring flight could become an established practice, five conditions had to be fulfilled. It was necessary to discover, first, that there is such a thing as soaring; second, how it is done; third, how to make a soaring apparatus; fourth, how to fly it; fifth—and not least important—to want to soar.

On the first point alone, two famous writers of the past reached opposite conclusions. Leonardo da Vinci, the versatile artist, scientist and engineer, who wrote on the flight of birds from about 1490 to 1515, knew that birds could gain height by sailing round in circles. But Giovanni Borelli, who in 1680 published a classic book on Animal Locomotion, thought that birds could only maintain height in a glide by using up momentum previously acquired by flapping. Unfortunately, da Vinci's writings were lost to the world for three hundred years, leaving Borelli as the standard authority.

Even up to the late nineteenth century many observers refused to accept the soaring of birds as an accomplished fact. Louis Pierre Mouillard, whose book, *L'Empire de l'Air*, published in 1881, inspired the brothers Wright, was exasperated by people who attributed his observations of soaring vultures in Egypt to an optical illusion. Others were so incapable of conceiving how soaring could be possible, that they could scarcely believe their eyes when they saw it done. For instance, H. N. Moseley, of the "Challenger" expedition (1869-73), would watch the albatrosses for hours in the hope of detecting a momentary

flicker of the wings; and Professor S. Exner, of Vienna, suggested as late as 1906 that birds with apparently motionless wings were really being pushed along by minute vibrations of the feathers.

The first clear explanation of the mechanics of soaring flight was given by Lord Rayleigh in a letter to *Nature* of April 5, 1883, where he stated that the wind must be either not horizontal or not uniform. The first of these conditions, which means in effect that the air must be moving upwards, is now known to be responsible for most of the soaring of birds and practically all human soaring. Yet even nowadays the great majority of people, educated or otherwise, are so unpractised in thinking in terms of relative motion that they cannot imagine how any object can move upwards relative to the earth while at the same time moving downwards relative to the air in which it is flying.

The earliest recorded attempts to fly, as well as the legendary ones, usually began with an attempt to reproduce a scaled-up bird's wing, often to the extent of putting feathers on it, in the belief that such a structure was inherently able to keep itself up, once it got well aloft.

The idea that the passage of a wing through air causes the air to react by holding it up was held by da Vinci, but later discarded by him when he realized that "a body cannot be pulled by the undulation caused by itself."

The same fallacy is said to have been held by Jean-Marie Le Bris in the mid-nineteenth century. In the course of his travels as a sailor he found that the wing of an albatross, when held up, drew forward into the wind and tended to rise. Having thus, as he thought, discovered the secret of soaring flight, he built a large glider in imitation of the bird and, about 1855, succeeded in getting it off the ground at Trefeuntec, near Dournenez in Finistère (France). It is related that he fitted the machine with controls, and that they worked.

A variant of the reaction idea was held by Dr. E. H. Hankin, who meticulously observed soaring birds in India from 1909 to 1912. He concluded that "soarable air" underwent some unknown physical change beneath a bird's wing, and refused to believe the up-current theory, except in so far as his birds would sometimes soar where the wind was being deflected upwards over an obstacle.

Fig. 1. *Otto Lilienthol flying his monoplane glider (about 1893). Note the slope of the hill, the glider's angle of descent is almost as steep.*

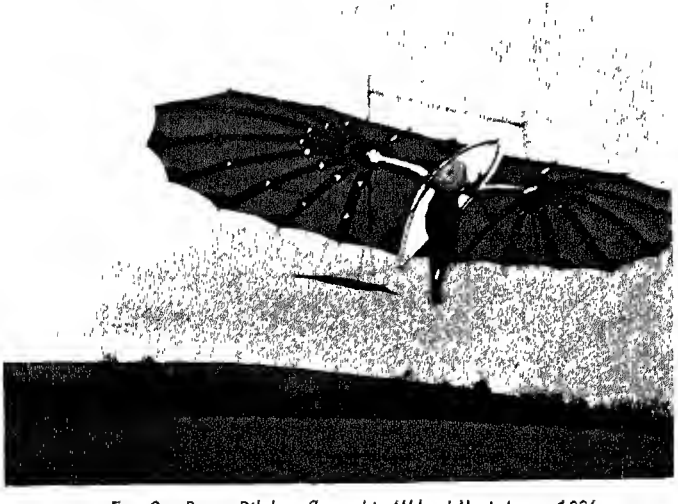


Fig. 2. *Percy Pilcher flying his "Hawk" glider in 1896.*

Human soaring in an up-current of this sort was first performed by Otto Lilienthal, if only for a few seconds at a time. He built a series of gliders from 1891 to 1896, when he was killed in a crash. Lilienthal realised the importance of continuous practice in controlling such a machine, which he did by moving his body about beneath the wing. He would jump off the top of an artificial hill near Berlin, or later from the

Rhinow Hills near Stöllen, and by 1895 was able at times to rise well above his take-off point in the ascending wind over the slope. But apart from this hovering over hills he appeared to have no conception how soaring was done, though some experiments with aerofoils near the ground led him to suspect that the wind was everywhere ascending at an angle of 3 or 4 degrees!

Percy Pilcher, a marine engineer who experimented with gliders similar to Lilienthal's from 1895 to 1899, first near Glasgow and then at Eynsford in Kent, also found himself able to hover momentarily over a slope. But he sought to prolong his flights, not by soaring, but by being towed with a cord, and while doing so he lost his life.

For many years the up-current theory had to contend with ts rival, the non-uniform wind theory. Even Rayleigh favoured the latter, and Samuel Pierpoint Langley, in his *Internal Work of the Wind*, published by the Smithsonian Institution of Washington in 1893, actually prophesied that the flying machine of the future would be able to "circumnavigate the globe without alighting" by using wind fluctuations alone, only resorting to motive power in "exceptional moments of calm".

A year later Octave Chanute forecast that the single-seater flying machine of the future would be a "soaring type," and only passenger-carrying aircraft would rely on continuous motive power. But even he could not at that time guess how soaring was done otherwise than in winds deflected up slopes.

Having advised all flying experimenters to concentrate first on soaring, Chanute decided in 1895 that he could not ask others to take risks without doing so himself. So he gathered a small band of helpers, and with them spent altogether eight weeks in the summer of 1896 among the sand dunes on the shore of Lake Michigan, near Chicago. Here they carried out some two thousand glides in winds ranging up to 31 miles an hour in machines with various wing arrangements, mostly designed by Chanute, who took a few hops himself although he was then 64 years old. At first he arranged for the wing-tips to swing back in response to gusts, finding that little balancing movement was then needed; later he fitted controls for the rudder and elevator. The gliders often climbed and hovered for several seconds at a time.

In the autumn one of his assistants, A. M. Herring, who had

flown a Lilienthal glider two years earlier, returned to the site and succeeded, by turning somewhat sideways to the wind, in soaring along a ridge for over 300 yards, keeping in the air for 48 seconds. Yet in the same year he had given his opinion, in the *Aeronautical Annual*, that soaring would not be accomplished until "long after the air has been navigated by steam!"

In 1899, Chanute decided finally in favour of the up-current theory, after satisfying himself that air often rises in places at more than four miles per hour. But in using that figure to prove soaring possible, this professional railroad engineer embarked on a complicated calculation involving foot-pounds per second and other entities. He then refrained from publishing this proof for many years on the curious ground that "to ensure safety, it would be necessary that the machine should be equipped with a motor in order to supplement any deficiency of wind force." In 1907, twenty-three years in advance of his time, Chanute described exactly how a glider should be flown when climbing in circles, except that, in advising the pilot to gain height only when facing the wind, he still showed a failure to understand fully the circling of birds.

After Herring, the brothers Orville and Wilbur Wright made the next advances in practical soaring. In 1900 they began experimenting with biplane gliders near Kitty Hawk, on the Atlantic coast of North Carolina, and by the autumn of 1903 they were able to maintain height over a sandhill for more than

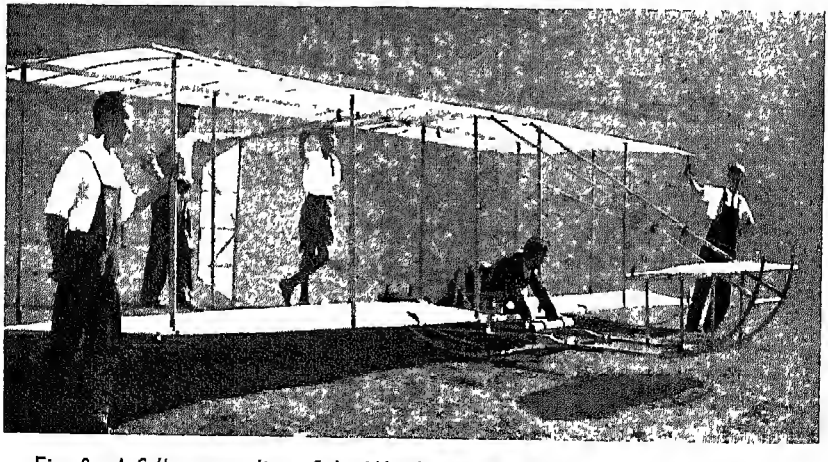


Fig. 3. *A full-size replica of the Wright glider of 1902, made by Messrs. Zander and Weyl for the film "Conquest of the Air".*

a minute on several occasions. They went one better than Chanute by adding lateral control.

The primary object of this soaring was to obtain longer practice flights than could be done by mere gliding descents, in preparation for the great day when the brothers could add a motor to the machine. But before their achievement of power-driven flight in December, 1903, turned their attention from the other kind, Wilbur had prophesied in 1901 that the glider pilots of the future would first learn to gain height over a slope and then go off across country to any desired spot by means of the other up-currents used by the birds. He and his brother had only been deterred from trying out this technique by the risk of landing in the marsh to leeward of their hill, and it was over a quarter of a century before anyone else was clear-headed enough to know how to set about it. A year later, in a paper read at Chicago, he used far simpler terms than Chanute when he explained that "the soaring of birds consists in gliding downwards through a rising current of air, which has a rate of ascent equal to the bird's relative rate of descent."

From the fact that birds usually circle in groups, Wilbur Wright deduced that the currents they use are localised. But the first full and correct explanation of circling appears to have been given by Wilhelm Kress in his book *Aviatik*, published in Vienna in 1905. Kress said that the up-currents which rise from warm ground on sunny days are so narrow that birds must fly in circles to keep within them.

Although soaring flight had now been not only performed by man but also satisfactorily explained, the fact aroused too little interest to become generally known, and even in 1908 Sir Hiram Maxim could declare: "We shall never be able to imitate the flight of the soaring birds." Some investigators, such as Gustav Lilienthal (Otto's surviving brother), still held to the "reaction" theory discarded by da Vinci four hundred years earlier. And José Weiss explained the soaring of birds, other than over a slope, by asserting that a perfectly designed wing should glide on a practically horizontal course, the only resistance being that due to skin friction. He built a large number of bird-like models without tails, and then a man-carrying machine in which, in 1909, E. C. Gordon England

was launched off Amberley Mount, in Sussex, rising about 100 feet in the wind blowing up the hill.

An opportunity to explore the higher up-currents was missed by Professor John J. Montgomery, who experimented with gliders between 1884 and 1911 in California. In 1905 he had his gliders released from balloons at 4,000 feet, and one of the pilots passed through clouds on the way down without being aware that they might have contained rising air.

A remarkable soaring flight of five minutes' duration in a biplane of Lilienthal type is stated to have been made in September, 1909, by Raymond Hekking, who flew it in a wind of 20 miles an hour at Larcouet, near Havre. The flight was recorded in the *Petit Havrais* of September 7, but otherwise passed quite unnoticed at the time.

Then, in 1911, Orville Wright returned to Kitty Hawk to try out a control device and also do some soaring. The soaring trials reached their climax on October 24 when, out of twenty-five flights in a wind of over 40 miles an hour, he made one of 7¼ minutes and another of 9¾ minutes. Sometimes he hovered, and at other times worked sideways along the hill over a "beat" a quarter of a mile long.

This last flight remained a world's record for a period of ten years during which hardly a single experimenter thought soaring flight worth developing for its own sake, and gliding was regarded merely as a preliminary to power-driven flight. Just as the pleasures of ballooning weakened the urge to invent an aeroplane, so the latter's eventual success delayed the advent of the sailplane, or soaring glider.

So also has the later mastery of the art of up-current soaring turned people's thoughts from the other sort described by Lord Rayleigh in 1883. This kind, known as dynamic soaring, makes use of irregularities in the wind flow, and a full mathematical treatment of it was published by F. W. Lanchester in his book *Aerodonetics* in 1908. One variety, practised by the albatross, is made possible by the increase of wind speed with altitude, and gliders often gain extra height in the same way just after a launch into a strong wind. It is also possible to take energy from gusts, and this is often done momentarily by both gliders and birds.

The first pilot to exceed Orville Wright's record in soaring flight, Friedrich Harth, used a machine in which the angle of

incidence of the whole wing could be varied directly by the pilot, instead of by the slower method of using the elevator as a lever. Harth began experimenting in 1914, with Willy Messerschmitt as assistant, and by August, 1916, had succeeded in maintaining height for 3½ minutes above the Heidelstein in the Rhon Mountains, north-east of Frankfurt am Main. Finally, on September 13, 1921, Harth kept up for 21½ minutes in a wind of 25 miles an hour at the same site, landing only 40 feet lower than his starting point. It was claimed that the ground below had an average slope of not more than 6 degrees, and

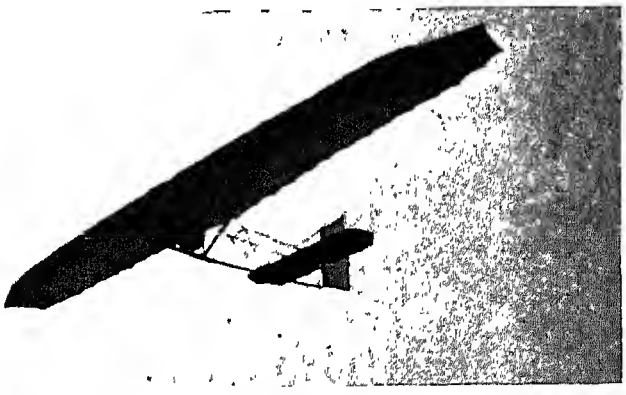


Fig. 4 *The Harth-Messerschmitt glider in which Friedrich Harth put up a world's record of 21 minutes, in 1922. The longitudinal control was effected by moving the whole wing, thus facilitating the use of gust energy.*

that therefore most of the lift was obtained from gust energy. By using gusts during which the wind would increase momentarily to 40 miles an hour or more, he was able to climb step by step nearly 500 feet above ground level.

Meanwhile, the up-currents were coming into their own again. These same Rhön Mountains had been used for gliding trials by a group of students from Darmstadt between 1912 and 1914. And to the Rhön in 1919 came Oskar Ursinus, editor of the pioneer journal *Flugsport*, taking a holiday, as he relates, after the shock of learning of the treaty restrictions on aviation in Germany. No aeroplanes could be built or imported for a period which was extended to May, 1922; restrictions on the performance of aeroplanes were then imposed, but removed in 1926,

after which, however, no public funds might be used to train any but commercial pilots.

Recollecting the gliding that had been done there before, and seeing some buzzards soaring over a spur, Ursinus was inspired with the idea of encouraging grounded pilots to get back into the air without motors, and called a meeting for the purpose which was held on the Wasserkuppe, the highest of the Rhön mountains, from July 15 to September 17, 1920.

Fig. 5. *W. Klemperer flying the Aachen monoplane "Blaue Maus" at the Wasserkuppe, in* 1920.

Although, like most of the earlier pioneers, he had hoped to develop soaring as an aid to the evolution of an efficient light aeroplane, Ursinus set going a series of annual meetings which established soaring flight as an art and science in its own right, and not as a mere stepping-stone to some other end.

The 1920 meeting brought some descending glides and a few short soaring flights of less than a minute. But while it was going on, a tailless glider designed by Wenk soared for more than two minutes over the Feldberg in the Black Forest; the

pilot, Peschkes, flew along a beat nearly 1½ miles long in a wind of 20 miles an hour.

At the 1921 meeting on the Wasserkuppe several machines of improved design turned up, and some prolonged glides of up to 15 minutes were made, one of which, by Otto Klemperer, included ten minutes' continuous soaring.

About this time much attention was still being paid to the possibility of using wind fluctuations. Klemperer tried flying across the wind and swaying in response to the accelerations from either side, but gave it up after he had nearly swayed himself into the hill. However, attempts at dynamic soaring were practically given up after the spectacular meeting of 1922 showed what up-currents can do, though a few designers still produced wings intended to take advantage of the "Knoller-Betz effect," by which energy for soaring can theoretically be obtained in a wind which rapidly fluctuates in direction alternately above and below the horizontal.

At this 1922 meeting Arthur Botsch first showed how to soar in a slope up-current. Then, on August 18, Arthur Martens, in the sailplane "Vampyr", soared over the west slope of the Wasserkuppe for 42 minutes and climbed 355 feet in a wind varying between 18 and 8 miles an hour; after this he flew out over the valley and glided down to a landing 6 miles away. He had been in the air altogether an hour and six minutes, of which the first 53 minutes were above the starting level. Next day F. H. Hentzen kept the same machine up for two hours, and on August 24 he raised the record to 3 hours 6 minutes, climbing over a thousand feet in the up-current and landing higher than where he had taken off.

Thus the possibility of prolonged soaring flight by man was established beyond doubt. It had been proved before thousands of witnesses and the news of it travelled round the world.

Having reached the most outstanding event in soaring history, we may pause to ask why such substantial results were not achieved before, since man's urge to perform effortless flight like the soaring birds had existed for thousands of years during which he had all the materials needed to make a sailplane. Probably H. G. Wells gives as good an answer as anyone when he writes that the glider "has had to wait throughout the ages until the fruits of scores of remote explorations and

discoveries had filtered down to practical exploitation. It could not have happened earlier than it did, and only as a consequence of that fundamental work".

This explanation may take us down to Lilienthal's time, but further delay in exploiting the new art has been attributed likewise to slowness in the advance of aerodynamic knowledge and structural design. Yet this need not have prevented a lot of soaring, for Lilienthal had already hovered over a hill and his pupil Herring sailed along a ridge. The most that can be claimed is that these technical advances have enabled soaring to be done in lighter winds, so that Martens, for instance, managed to keep going during a critical lull when the wind on the Wasserkuppe dropped below eight miles an hour.

His "Vampyr" came through this ordeal because it was designed for the lowest possible rate of sink through the air. The pilot's body was enclosed in a streamlined fuselage and the hole through which he entered it was covered in with a leather fairing up to his neck. The wing as originally planned had a mean aspect ratio as high as 10 to 1, and a thick wing section had been evolved which needed hardly any strutting and could be stiffened by a single main spar and a plywood leading edge to take torsional stresses. The latter was an innovation in aircraft design and has subsequently been adopted in nearly all sailplanes and many aeroplanes.

While all these improvements were helpful, they were not essential for soaring in strong winds. One novel feature, however, distinguished the efforts which brought such success in 1922. This was that encouragement and help, instead of ridicule or apathy, were at last offered to those restless dreamers who persisted in wanting to soar like the birds in a world caught up in the aeroplane age.

The "Vampyr" was created by co-operative enterprise, not by secretive inventors hoping to avoid detection or fearful of their ideas being purloined. Professor Pröll and Hermann Dorner (who had been inventing flying machines since Lilienthal's day) suggested the design; Dr. G. Madelung sketched it in; Martens, Hentzen and Walter Blume worked out the details, and the Hannoversche Waggonfabrik built it.

Among the 53 entries for the 1922 contest (not all of which turned up) were several other machines of good aerodynamic design which soared for periods of up to an hour and a half.

Some were built by university groups which have continued ever since to play a prominent rôle in the improvement of sailplane design.

Naturally the activities in the Rhön district stimulated attempts to soar elsewhere. But before the year was out the only real success was obtained at a meeting on the South Downs, between Newhaven and Eastbourne, organized by the *Daily Mail* and held from October 16 to 21. The need for turning along the slope immediately after a launch had first to be demonstrated by Antony Fokker, who had already flown his two-seater biplane at the Rhön. Later on, F. P. Raynham

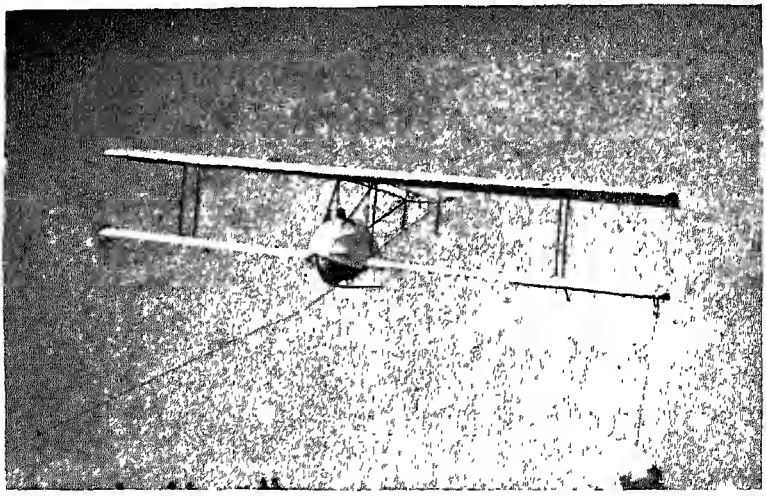


Fig. 6. *The Fokker biplane which put up new records for two-seater soaring both in Germany and England in* 1922.

soared for 1 hour 53 minutes, G. P. Olley with a passenger for 49 minutes (a world's record), and Alec Gray for an hour; finally, Alex. Maneyrol stayed up for 3 hours 21 minutes in a Peyret tandem monoplane, similar in design to Montgomery's balloon-launched glider of 1905.

This record was beaten three times in January, 1923: first at Biskra Oasis, Algeria, by Thoret in a monoplane with motor stopped; then at Vauville, again by Maneyrol, and later by Barbot (8 hours 36 minutes). Later records have been established in East Prussia, the Crimea, Hawaii, Sylt, Auvergne, and finally again in East Prussia, where Ernst Jachtmann soared

for 53 hours 52 minutes in September, 1943. The duration record for soaring flight, which began as a thrilling duel between man's intellect and the law of gravity, has now become primarily a test of endurance, although in fact most of the more recent flights have been made in awkward conditions which called for considerable soaring skill.

After the outburst of activity at the beginning of 1923, interest in soaring flight declined among all but the few persistent devotees. There was general doubt whether hovering noiselessly over the same bit of ground brought any satisfaction once the novelty had worn off. During the next five years only a handful of soaring centres remained active.

Vauville, near Cherbourg, was used again in 1925 for a meeting at which Massaux, from Belgium, put up a new duration record; and again in 1928, when a visiting team came from Germany.

Near the bird-ringing station at Rossitten, on the Baltic coast, a useful site was developed by Ferdinand Schulz, a schoolmaster, who set up new duration records there. It is on a long sandy spit with an almost continuous line of giant dunes rising in places to 200 feet, along which Schulz was able to soar 37 miles to Memel in May, 1927.

After a team from Russia had taken part in the Rhön meeting of 1925, the leading German pilots were invited to the Crimea and set up new world's records at Koktebel, near Feodosia. This site, consisting of a line of hills 600 feet high, had been used since 1923 for annual gatherings of Russian glider pilots.

Meanwhile, the Rhön carried on, and the Wasserkuppe remained the centre of pilgrimage for those who still hoped for the future. But all was not well there. The gradual resuscitation of aeroplane flying, coupled with lack of progress in soaring technique, caused both public and official interest to sag, and with it sagged the enthusiasm of many of those who had done the soaring in 1922. In the following year poor winds led to equally poor performances. Then, at the 1924 meeting, some glider-like aircraft with light motors took part; but as the Wright brothers had added a motor to a glider in 1903 (hence the aeroplane), this was merely history repeating itself and no new paths were opened up.

Late in 1924 the first steps were taken to surmount the critical situation that had arisen. A subsidised organization was

set going with the dual purpose, firstly, of facilitating the construction and flying of gliders by impecunious aviation enthusiasts all over Germany, and secondly, of promoting technical research into the further possibilities of soaring flight.

In 1925 this body, known as the Rhön-Rossitten Gesellschaft (R.R.G.), took over two gliding schools at the Wasserkuppe and Rossitten which had already been operating on a small scale. Then Alexander Lippisch, a talented aerodynamic expert and designer, produced a series of single-seater training machines of which the most famous are the Zögling, for teaching beginners to handle the controls, and the Prüfling, for elementary soaring. Both types appeared in 1926, and it then became possible for the first time to train beginners right through to the soaring stage, without the need of previous flying experience in aeroplanes such as all successful soaring pilots had hitherto had. Further, these types could be easily built and repaired by amateurs.

For the second object of the newly-formed Company, that of scientific and technical advance, the main inspiration came from Dr. Walter Georgii, ably backed up by Lippisch and the university groups in the matter of sailplane design.

Georgii, a leading meteorologist from Darmstadt, had published a book in 1923 on *Soaring Flight and its Source of Energy in the Atmosphere*. It was a sound book except for the author's assertion that "man will never be able to soar for any length of time with the help of thermal up-currents". He based this opinion on the belief that thermal currents rarely rise faster than 3 feet per second, that contemporary sailplanes sank twice as fast as this, and that they could not be turned in tight circles like the birds. In 1926, Georgii became leader of the R.R.G. and did all he could to encourage meteorological research into up-currents.

That same year saw the development of a new technique of cross-country soaring from hill to hill, climbing as high as possible above one hill and then gliding across the gap to the next. Johannes Nehring, of the Darmstadt group, became its leading exponent. He made a difficult flight from the Wasserkuppe to the Milseburg, 3½ miles distant, and back, in 1926; then in 1927 he increased the distance record to 38 miles, and in 1928 to 43 miles, in each case by using successive mountain slopes as stepping-stones.

But an even more notable event marked the year 1926. On August 12 Max Kegel, of Kassel, was soaring over the Wasserkuppe when a thunderstorm passed over. He was drawn upwards two or three thousand feet within the cloud, and by the time he could extricate his machine and land he had travelled 35 miles. Thus by a happy accident the soaring fraternity were liberated from their dependence on wind deflection over hills and vast new regions of the atmosphere were opened up to them. But not at first, for unfortunately Kegel gave such a harrowing account of his experience that no-one else felt like following his example. So for the next advance history had to wait two years.

In spite of Georgii's disbelief in the efficacy of the thermal currents which go up from heated ground in the daytime, he thought nevertheless that they might be strong enough to lift a sailplane where cumulus clouds formed in their tops, because the condensation of moisture into cloud liberates heat and so gives an extra boost to the up-current. So in the Spring of 1928 he arranged for Nehring to fly a light aeroplane up to the clouds and try to soar underneath them with the motor stopped. The attempt succeeded, and up-currents of 3 to 16 feet per second were found.

This research bore fruit at the same year's Rhön meeting when, on August 6, Robert Kronfeld made connection with the up-current below a passing cumulus cloud, used it to reach the Himmeldankberg 4½ miles away, and returned to the Wasserkuppe against the wind by similarly using a whole line of clouds in succession. Kronfeld had only started gliding the year before, and had never flown an aeroplane.

In the early summer of 1929 further metcorological research was done by the R.R.G., this time into the type of storm used by Kegel in 1926—a "line squall" or travelling line of thunderstorms caused by a "cold front", where warm air is forced up over a body of cold air coming in to replace it. It was found that a wide area of smooth rising current exists in the clear air in front of the storm, so there is no need to go inside the cloud as Kegel did.

Kronfeld, having first provided himself with a parachute in case of trouble, succeeded on July 20, 1929, in connecting with just such an up-current in a flight from the Wasserkuppe and landed 89 miles away. Ten days later he climbed through an

enormous cumulus cloud to 8,320 feet above the mountain, nearly half the climb being inside the cloud, and while descending from this record height he found weak lift in the clear air *above* the tops of the smaller cumuli. He finally soared along a mountain chain and landed near Bayreuth after covering 93 miles.

These striking new developments made little or no impression on the general public, but the aeronautical world realised the significance of what was happening, and some talked of reviving an interest in soaring. A few actually tried to get

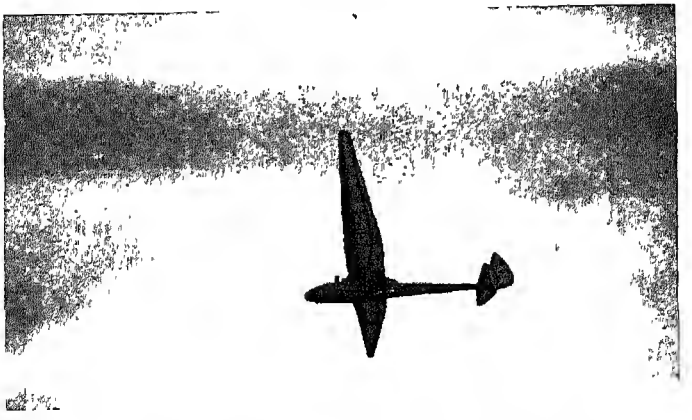


Fig 7. *The "Wien" sailplane in which Robert Kronfeld set up spectacular records for cross-country soaring flight in* 1929.

some soaring done, though they still had no idea how to do it except by the now old-fashioned method of staying over a slope.

It is at this point that those administrative units, the Sovereign States, break in upon our story, which began as an effort of the human race to achieve by guile what the birds perform by instinct.

First, the Germans discovered that, by promising to get quantities of "youth" into the air without the expense of a motor, they could raise enough public funds to effect qualitative improvements in the technique of soaring. Thus the best pilots could be made instructors and so enabled to live on a soaring

site; the skilled designer could exploit his talents for a living; and the meteorologist could carry out expensive research into vertical currents.

About 1927 the Russians began an intensive development of gliding all over the country in connection with their "five-year plan", but practically the only real soaring was done at the annual meetings at Koktebel. At the end of ten years 140,000 glider (not sailplane) pilots were reported to have been trained.

In Poland the first soaring attempts were made in 1923, but success first came in May, 1928, when Szczepan Grzeszczyk kept up for 7 minutes and netted a government subsidy of £120 for his group. Next year a flight of two hours created such a sensation that a large training organisation was set going with government help, and Bezmiechova in the Carpathians, where the flight was made, became the national soaring centre. In addition, in 1932, a technical research institute was set up in Lwow University; it has investigated thermal currents and other phenomena, and produced a "thermal map" of Poland showing the distribution of cumulus cloud.

The visit of two Frenchmen, Auger and Abrial, to the Wasserkuppe for an instruction course in 1927, led to the revival of the Vauville site in 1928 and the setting up of a national organisation, L'Avia, in 1929, on the initiative of Pierre Massenet. A subsidy of a million francs was secured in 1931 and the Banne d'Ordanche, in Auvergne, developed as a national centre.

A British Gliding Association was founded at the end of 1929 and soon began angling for a subsidy, which, however, failed to materialize till five years later. Kronfeld paid a visit and soared 50 miles along the South Downs in June, 1930. A large number of gliding clubs was formed, but many of them petered out, and for the first few years almost the only soaring was done at Dunstable Downs by some members of the London Gliding Club.

So the tale goes on for other European States. Subsidies, if any, would come from a government department, or an Aero club, or a rich industrialist, and people hopped about on primary gliders, but little soaring was done.

In America nobody exceeded Wright's record of 1911 until a small German mission arrived in 1928 and Peter Hesselbach

soared for 4 hours 5 minutes at Cape Cod, south of Boston. A gliding school was started there, but soaring flight as such aroused little interest for the next two years. Then W. Hawley Bowlus began designing high-performance sailplanes, and soared one for 9 hours at Point Loma, in California, early in 1930. Professor R. E. Franklin designed a glider, the "Utility", suitable for towed flight and for all stages of instruction, including soaring. And a national centre was founded at Elmira, a hilly district in New York State, where annual contests have been held ever since.

To the first contest came a visitor from Germany, Wolf Hirth, perhaps the best known sailplane pilot in the world, owing to his habit of visiting various countries to persuade and help people to improve the quality of their soaring—a necessary antidote to the national subsidy distributors with their quantitative outlook.

On October 2, 1930, Hirth took off from Elmira into an absolutely cloudless sky and travelled 33 miles across country by using invisible thermal currents. He climbed in them by going round in tight circles, having first found them by watching where another sailplane was getting extra lift, or where birds were circling; or else by the indications of his variometer, or rate-of-climb indicator, an instrument first used by Kronfeld in 1928. This is one of the outstanding flights of soaring history, as it has set pilots free from both hills and clouds. Thermals, as they are now called, can be used either at low levels where clouds do not indicate their distribution, or higher up when no clouds are there to help.

In the Spring of 1931 thermals over flat country around Berlin were explored, the sailplane pilots being towed up behind an aeroplane and then cast loose. This method of launching, soon to come into widespread use, was first demonstrated by Gottlob Espenlaub at Cassel in 1927. Instruction courses in aeroplane-towed flight were instituted at Darmstadt, and Günther Groenhoff used this method of launching to start on a record flight of 169 miles from Munich into Czechoslovakia, using a "cold front" storm.

For three years it was believed that long distances could only be achieved on cold fronts, until in 1934 and 1935 distances of up to 313 miles were flown from the Wasserkuppe by using the continuous belts of up-current associated with long rolls of

cumulus known as "cloud streets". Since then greater distances have been flown by the same means, the present record being one of over 460 miles by Miss O. Klepikova in Russia. Russian pilots, in fact, now hold all the world's distance records for soaring, having made great progress since they gave up their hill site in 1937 and held their annual contests in flat country with aeroplane-towed launching. The Poles made a similar change at the same time.

Altitude flights are likewise undergoing a change of technique. Till 1938 they were almost invariably performed by flying inside a cumulo-nimbus, or isolated storm-cloud. But on March 3, 1933, Hans Deutschmann was carried up to 4,600 feet in a stationary wave of air over Hirschberg, to leeward of the Giant Mountains in Silesia, where a foehn wind descended after crossing the Schneekoppe mountain and then rebounded up again. In subsequent years greater heights were attained there until, on November 21, 1938, Erwin Ziller set up the present official record climb of 22,429 feet.

Similar "standing waves" have now been found, and soared in, elsewhere. For instance, in an experimental flight to leeward of the Alps a sailplane has reached 30,000 feet above sea level, and it is not improbable that such regions of lift may extend into the stratosphere, and that they can be created by cold fronts as well as by mountains.

Another unexpected source of lift was first discovered by some Polish pilots who found they could soar at Bezmiechova in almost dead calm air for some hours after sunset. Investigation showed that shallow masses of cold air were flowing down the hillside, which had cooled by radiation to a clear sky, and were apparently displacing warmer air upwards out of the valley bottom. This phenomenon has also been found in other countries.

A type of up-current along coasts, where the "sea breeze" undercuts heated air rising from the land, has been exploited particularly in England, where it offers a means of prolonging distance flights which would otherwise be stopped by reaching the sea. It was used by Philip A. Wills in setting up the present British distance record of 209 miles on April 30, 1938. The sea itself does not as a rule send up strong thermal currents, and the crossing of the English Channel by Geoffrey H. Stephenson on April 22, 1939, was done by climbing in a cloud

current that had originated over land, then gliding the rest of the way across. However, the regular lines of cumulus over the warm seas of trade-wind regions suggest that cloud-current soaring over the ocean may be possible there, and if so, it could be carried on round the clock, since the sea does not cool perceptibly at night.

Soaring among high mountains has its own peculiar meteorological problems. The pioneer in this field is the Swiss pilot Hermann Schreiber, who made the first soaring flight across the Alps on September 7, 1935, flying from the Jungfraujoch to Bellinzona on a devious course of 90 miles.

Thermals over desert country have been explored in the southern United States and Egypt, and in sub-tropical regions in South Africa and Australia, but not yet, strange to say, in India. The Russians have shown that sailplanes designed for high speed perform especially well over wide plains.

While the longest cross-country soaring flights are necessarily made directly down wind, in recent years pilots have shown increasing skill at travelling across wind and even up-wind. Flights to a previously announced goal, which may involve working across the wind, were first attempted at the Rhön in 1934, and the present "goal flight" record, 373 miles, was set up in Russia by P. Savtzov in July, 1939.

Out-and-return soaring flights are a more interesting development, as they necessitate travelling against the wind for one half of the flight; they are usually done on days of light winds. The present record of 212 miles was also set up in Russia in July, 1939, the pilot being Boris Kimelman.

Still more ambitious is the "round tour", initiated in Germany in 1936. Pilots are given a week or more to cover a prescribed course of several hundred miles; at the end of each day's soaring they have to land on an aerodrome from which they can be towed up again next morning. The logical outcome of this, it has been suggested, is to follow the migration routes of the birds; storks, for instance, are known to carry out most of their migrations in thermal currents, climbing in each one and then gliding on to the next.

What with increasing progress towards the ideal of being able to soar anywhere at will, and the prospect of reaching the stratosphere, there is enough to exercise the wits of the world's soaring pilots for many years to come. And if this is not

sufficient, the whole field of dynamic soaring has yet to be explored and conquered. On March 18, 1937, Albert C. Slatter put on the mantle of Harth, unworn for sixteen years, and used gust energy to maintain height in a squally wind off the Pacific coast of North America near Hollywood, 2,000 feet above the sea.

And for the adventurous, there is the problem of soaring like the albatross in the "roaring forties" of the Southern Ocean;

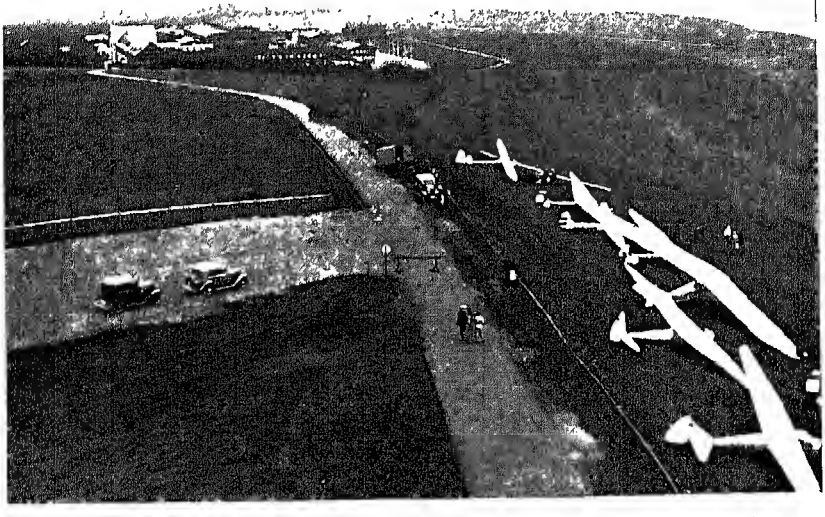


Fig. 8. *The German gliding headquarters on the Wasserkuppe on the occasion of the International Soaring Contests in July, 1937, showing also the South Slope. The large machine is the British "Falcon III", and in the right-hand bottom corner is the British "King Kite".*

but this must wait upon a suitable life-saving device, though an inflated "Boynton dress" was suggested for the purpose by Thomas Moy in 1884. Allied with this is the idea of being carried along, as many sea birds are, in the rising aerial wake of a steamer.

Soaring, therefore, has a future fully as bright as its past. But it needs emancipation from its too frequent reliance on "gliding" subsidies, themselves only forthcoming when there is a war in prospect; and from apologists who put it forward as a mere preparation for aeroplane flight, rather than continue

their uphill task of convincing the aviation world that soaring has its own sphere of development quite apart from other modes of flying, with its own problems for the scientist and technician, and its own satisfactions for the adventurous. The cloud currents, the heat turbulence, high winds and mountain overfalls, which the aeroplane pilot finds so unpleasant or even dangerous, are regarded by the sailplane pilot as friends, not as enemies. He does not fight against the forces of Nature; he uses them for his own ends.

Chapter 2

LAUNCHING METHODS

THERE are several methods of glider launching in general use to-day, and each has its own particular advantage under certain conditions.

These different methods also vary in technique, and whereas in some cases the glider can be launched by unskilled bystanders, in others the degree of skill of the launching man, or team, must be high

The methods most usually employed are bungey (catapult) and hand launching, auto-towing, winch launching, and aero-towing. Some experiments are at present in progress to find out the possibilities of economic rocket launching, which would permit the pilot to be independent of a ground crew.

Bungey launching

Bungey launching was first brought into general use by the Germans during the revival of gliding following the last war, and it provided for them an efficient and extremely cheap method of getting machines into the air: it required a considerable crew for each launch, but man-power (later the Hitler

Fig. 9. *Bungey launch of Primary on flat ground.*

Youth) was available in quantity. It also required the existence of a hill from which to make all but primary training launches, as the bungey launch will not give height for more than a few seconds flight from flat ground (Fig. 9). Hill sites were also available to the Germans in quantity.

When the gliding revival began in Britain, bungey launching was used for both soaring and training launches, but club members soon tired of continually pulling off other people in order to get a few seconds flying themselves, and this was one of the causes of the drop in club membership at that time. The reduced number of members was often insufficient to give proper launches to those who did turn up, so auto-bungey launching was developed. This merely meant that a car stretched out the rubber rope instead of a human team: it was not satisfactory on the whole, as the car often failed to leave a clear landing path for the training glider, and the pupils' concentration was frequently interrupted by trying to make certain of avoiding the car in front of him. Another danger during early training by this method was due to the launches being sometimes too strong for the pupils abilities, with consequent expensive results.

Bungey launching is, however, an extremely useful method of launching sailplanes from hill sites when away from established clubs, and many private owners keep a bungey in their trailers for this purpose.

The principle of bungey launching is as follows:

The bungey is composed of a large number of rubber strands bound with cotton. There is a ring fitted in the centre of this rubber rope for attachment to the launching hook of the sailplane, and at each end there is a length of knotted cotton rope which is held by the launching crew. When a launch is to be made the ring is hooked on and the two ends of the rope drawn out forward of the glider in a V (Fig. 10). The tail is anchored and the launching crew pull out the bungey as fast as they can. When the required tension has been reached, the tail is released and the machine shoots forward into the air.

The words of command given by the pilot or instructor must be made clearly. 'Walk', followed by 'Run', as soon as the crew have got moving; and, 'Release', when the cord is stretched to nearly double its normal length. If there is a strong wind blowing the pilot can give the 'Release' command earlier. The

Fig. 10. *Bungey crew preparing to launch as seen from the pilot's seat. At present the crew are far too close together and might be hit by the machine as it took off.*

pilot should see that the machine and launching team are placed in the best position on the hill top for the launch. If they are too far back from the edge there may be a danger that the machine will touch down again before getting clear, and merely slither down the hill with the possibility of damage: on the other hand, the machine should not be so near the edge that the launching crew are in danger of falling, or getting out of control, as they run down the slope.

The bungey launching ring should always be put on an open hook and *never* fitted into a quick release. As regards the anchorage of the glider, this can be done by attaching the tail to a stake in the ground *via* a reliable quick release, although it is wise to additionally instal a weak link. The safest form of tail anchorage is, however, the human one, especially when auto-bungeying, as the acceleration of the car may be so rapid, that it will break the bungey and cause it to fly back on to the machine and pilot, if the tail is anchored too firmly.

For heavy machines, or where a powerful launch is required, two or more bungies can be used together, although this must naturally mean an increase in the number of the launching crew. For normal launching under average conditions, there should be at least three a side on the bungey, and this would increase to 7–10 per side when more than one bungey is used.

In strong winds with a single bungey the number of men per side can be reduced to two or even one, provided they are sufficient to give the machine flying speed.

The British Services Gliding Clubs in Germany have speeded up training launches by bungey, by pegging the forward ends of the bungey into the ground, and drawing the glider backwards from the apex of the rope by car until sufficient tension has been reached, when the glider has been releaxed.

Fig. 11. *Kirby Kite leaving bungey after launch from hill top.*

During a bungey launch, the pilot will get the best results by flying straight forward in his normal flying attitude until the bungey has fallen clear (Fig. 11), when he may turn any excess speed into height. He will gain nothing by following the bungey in a dive, and may lose a great deal of power from the launch by pulling up too rapidly and causing the bungey to fall off prematurely.

The bungey method of launching is not very satisfactory for training purposes, as the sudden acceleration of the start is not helpful to a pupil whose mind is already too full of what he must and must not do. Also, once the flight has commenced the instructor has absolutely no control over the pupil's actions. Thirdly, the duration of flights are so short that the pupil has landed, often before he really realises that he has taken off, and has no time to correct any faults.

Bungies should be carefully looked after, as although the

rubber strands may seem to be well protected by the braided cotton covering, exposure to oxygen and contact with oil and grease quickly ruin the elastic properties; petrol will cause the strands to swell up, and if the bungey is used in this condition, it will break. Water does not affect rubber at all, in fact submersion in water will prevent oxidising, but is not practicable as water soon rots the cotton covering.

Bungies should never be stretched out more than 100 per cent, as this will put part of the load on the inelastic cotton covering with consequent risk of damage.

When being stored, bungies should be dry, and hung up in a dark, draughtproof shed.

When the speed of the wind is above the minimum flying speed of the glider, hand launching can be resorted to, although this method should not be used unless the pilot is fairly experienced. The machine is carried to the very edge of the hill where it should be just "flying", that is, with the controls in operation and the wing lifting. With a man under each wing, clear of the tailplane, the machine is lifted up and "thrown" over the edge. If conditions are right there will be little or no effort required to do this.

Auto Towing

Auto towing (Fig. 12) came as the logical development to bungey and auto-bungey launching. First of all the bungey was stretched out by a car, then a length of rope was inserted to increase the distance between car and glider; and finally the bungey was eliminated and the tow rope lengthened as required, for either training purposes, or high launches.

The car and sailplane are coupled by means of a tow line of the required length (normally between 300′ and 2000′) which is attached at both ends *via* quick releases, and with a weak link at the glider end.

The launching crew required is usually two, a driver, facing forward, and the instructor, or director, facing the glider, but near enough to the driver to give him instructions without difficulty or delay, and who is also in control of the quick release. The ground distance required for high launch auto-tows is considerable, as the cable must first be laid out in a straight line between the glider and the car, which should then be able to travel forward at roughly the flying speed of the aircraft long

enough for the glider to gain the maximum height for the tow line length in use. A total run of about 3500′ would be needed if the tow line is 1000′ long. The distances required usually limit the use of auto-towing.

The launch should be made, if possible, without any change of gear, and the initial acceleration should be as rapid as possible, so that there is no possibility of trailing or damaging a wing tip before flying speed has been reached. This is fairly easy when only training launches are required, as trainers usually have a low flying speed and the launch can be made in low gear which greatly facilitates the start. For fast heavy

Fig. 12. *Primary glider being auto-towed on short cable.*

machines, in conditions of light wind or calm, it is usually difficult to satisfy the pilot on both the start and the climb, without a change of gear. Gear changing is not, however, impossible, and provided the change is quick, the pilot has knowledge of its coming, and it is not made when the sailplane is only a few feet off the ground, the result will not be difficult or too uncomfortable for the average experienced pilot. Gear changes should, however, never be made on training launches.

Once the car driver has slowly straightened the cable, and then accelerated to get the sailplane off the ground and flying

satisfactorily, his speed should be regulated so that the air speed of the glider (not ground speed of glider, or speed of car) is kept about 5-10 m.p.h. above the best flying speed, and the only satisfactory way in which this can be done is by experience. No indicator can give a true idea of the changing loads on, or the speed of, the machine. (For further notes on the behaviour of the machine while on the rope, refer to page 40, on winch launching.)

At the end of a good launch the glider should be almost above, and a little behind, the car in normal flying attitude, and at this point should release. If the glider does not release, the cable should at once be freed from the car end.

It is essential that a second man should be used to watch the glider, unless the driver is so certain of his run and car, that he can be sure that he will not take his eyes off the machine at any time. The second man's job is to correct the drivers speed, and inform him of any emergency. He will not have much to do normally when launching experienced pilots, but will have a most responsible job when on training, as often it is only an immediate check, or a burst of speed, that may prevent the pupil from damaging the machine.

As regards the pilot, as soon as he feels that the machine has become airborne, he should raise the nose in order to climb at the steepest angle that seems comfortable and safe. If the launch is too fast he will notice this at once in his high airspeed and stiffness in the controls, and should put the nose down. If he is still too steep the machine may start bucking fore and aft, which is neither comfortable, safe, nor adds any height to the launch. If the launch is too slow, the pilot will feel that the machine is "mushing" through the air, and should lower the nose in order to maintain plenty of speed. He should release when he is no longer gaining any appreciable height, and when the car seems almost below him. At this point he should be flying in normal attitude and at normal speed.

The disadvantages of auto-towing are that a great length of run must be used, and that some of the power of the engine must be used in accelerating and moving the whole weight of the car during the period of the launch. It is usually necessary to have a second man to assist the driver. It is often not easy to give a fast heavy machine an all round good launch unless a very-high power car with excellent acceleration is used.

One advantage, however, is that provided there is safe attachment for a quick release, and the launch director can at all times see the glider being launched, any suitable car can be used, without the necessity of any conversion or alteration being made.

In calm weather it is also possible to drive round and round a suitable perimeter track with a sailplane on tow, until thermal lift is encountered.

Winch Launching

Winching has become one of the most widely used methods of launching gliders and sailplanes (Fig. 13).

Fig. 13. *Winch launch of Kirby Kite: note wire guard in case of cable breakage.*

It does not require quite so much ground space as for autotowing, and in addition, the field surface need not be as smooth or free from bogs, or soft patches, as would be required when the launching car has to be driven across it, even ditches or ridges do not interfere. The power of the engine can be wholly used to launch the glider, and is not required for moving the car. The driver is also facing the glider he is launching and can

correct instantaneously from his own reaction without the need for a director. Two disadvantages are; those requiring a specially converted piece of machinery, and the fact that the cable cannot be released at the winch end in an emergency and has to be cut, necessitating a carefully made join before launching can re-start. From the point of view of the established club, however, the winch method is highly satisfactory.

The principle of the winch launch is that the winch drum shall wind in the cable, to which is attached the glider, fast enough to enable the glider to become airborne, and climb as high as possible, before reaching a point nearly above the winch when no further height can be gained, as the remaining pull is only downward. The glider then releases the cable.

Winch launching is a good method of training pupils solo, as the pupil can have as long a training run or flight as the length of field allows. It does not matter how long the cable is for early training, provided the winch driver (instructor) can still see clearly what the machine is doing. The only disadvantage of a very long cable is its weight, although this is more important on high launches, when the sailplane has to carry the load of the cable, than on training launches, when much of the cable remains on the ground.

A fair estimate of height of full launch to length of cable laid out is, under normal conditions, about one-third, that is; a machine well launched with 3000′ of cable out should almost reach 1000′. With a centre of gravity release hook, nearly half the cable length can be turned into height.

The winch driver, on receipt of the 'take up slack' signal from the sailplane end, should pull in the cable slowly until it is straight, and this is very important when giving training launches. A curved, or bowed, cable with the resultant slight sideways pull at the start of the launch does not matter very much with a pilot whose flying has become instinctive, but any little distraction early in the pupil's launch may upset him for the whole flight.

When the tow line is taut and the 'Full Out' signal is received (this is only a check signal as the winch driver will be feeling the pull on his engine), the winch driver should have the clutch almost in and the engine running at a very fast tick over. As he begins to rev. up in order to take the machine off, the clutch should be fully in. The power should be increased

as rapidly as possible consistent with smooth running, until the machine is airborne and, for a full launch, starting to climb steeply. Power should then be reduced gradually and steadily as the machine gains height, especially if the wind is strong. To launch a fast machine in calm conditions may require half to two-thirds take off power at the point of release, whereas in a strong wind the winch engine may be just ticking over at this point (Fig. 14).

Fig. 14. *Derby and Lancs. Club winch in operation.*

If the winch driver sees the machine bucking during the launch he should reduce speed, as either the whole launch is too fast, or the pilot is pulling up too steeply. In either case sudden gusts will put a severe strain on a machine already heavily loaded.

The pilot is responsible for giving instructions to the winch *via* his signaller, and a smoother launch will be obtained if the cable is taut and straight before the 'Full Out' signal is made, especially if the glider is on a down slope. If the cable gets temporarily caught round a tuft of grass or other obstruction, the glider will start to move forward, and then probably over-run the cable. When it frees, the slack will then be taken up with a jerk. More ground distance, and therefore height, will

be lost in this manner than by allowing the glider to be pulled slowly forward a few feet before giving the 'Full Out' signal.

As soon as the machine is fully airborne the nose can be pulled up steeply, for it is on the first third of the launch that the most height will be gained. Obviously this pulling up should not be overdone; in case of winch failure, or cable breakage, which would leave the machine in a stalled attitude with little height. The normal fault of the beginner is not to pull up steeply enough, which may result in his not gaining sufficient height to complete a circuit and land into wind again.

As has been stated, the greatest proportion of the height gained on the launch will be gained immediately after take off, when the pull of the cable has the greatest horizontal, and the least vertical component, permitting the machine to climb steeply. As the launch progresses, and the machine traverses the distance between take off point and the winch, the downward pull on the cable will steadily increase and the machine be forced to climb less and less steeply (Diag. 1).

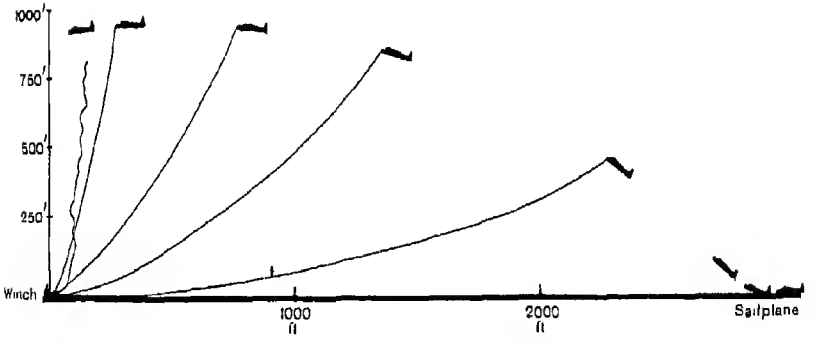


Diagram 1

If the nose is held up by force, bucking will follow, with its strain on the machine, but no improvement in height gained. The last third of the launch is the least good for gaining height, as the machine is approaching normal flying attitude, but a certain amount of height is gained, and anyway, the finish of the launch is much smoother if the machine flies off with normal speed and in normal attitude then jerking off the cable with the nose still high. The beginner will rarely carry the launch to its proper finish, and in his fear of over-running the winch usually releases far too early.

Trials have been made with the cable connected to quick-release hooks situated at varying points between the nose and the centre of gravity of the sailplane. The farther aft the hook is placed, the better the height gained on the launch, although if placed too near the C.G. fore and aft instability is likely to result, with dangerous consequences.

In 1938 and 1939 several pilots in this country were experimenting with gaining further height by remaining attached to the winch cable in high winds, and "kiting". The procedure is to get as high as possible while being launched normally, then continue facing into the wind flying as slowly as is safe. At the end of the normal part of the launch, the winch is almost stopped and the cable winding in only very slowly, if at all. At this point the winch driver puts the winch out of gear and slowly starts pulling the cable out once again. If the wind is strong enough the machine will take up any slack and gain further height. If, however, the wind is not strong enough, the machine will travel forwards, passing over the winch in order to keep speed, and the pilot should release as soon as possible. Heights up to 2700′ have been gained in this way in this country, when the height of the normal launch would have otherwise been 7-900′, and the glider has remained on the cable up to half an hour.

Kiting should never be attempted by any but experienced pilots, and the launching cable should be as light as possible, so as not to overload the glider. Even 2000′ of 10-cwt. cable weighs 44·4 lbs.

Kiting can be useful on days of very strong wind combined with good cross-country weather. Near the ground the air is turbulent, and thermals are broken and difficult to circle in. It is also difficult to circle at all without drifting too far to make a certain return to the landing field. Aero towing as well, can be most unpleasant low down on really rough days. By means of kiting to a height of 1800 - 2800′, the glider not only obtains enough height to circle in lift without risk, but is in a position to take advantage of direct cloud lift, the less turbulent air, and expanding thermals, away from the lower levels. Very little has been done in this respect so far, and there is much room for further valuable development.

If the winch could give 1500′ of height on every launch with 3000′ of cable out, it would be absolutely unbeatable as a method

of getting gliders into the air as regards general practicability and low cost, and several people are working on ideas or methods to improve the height gained on the launch in other than strong wind conditions.

One method which was just having its first trials when war put a stop to them was being developed by R. C. G. Slazenger, and consisted of climbing normally on the launch, but instead of releasing at the point of maximum height, the pilot turned downwind away from the winch while the driver pulled out sufficient cable to compensate for the increasing distance between the glider and winch. When nearly above the original launching point and down to about half the original height gained from the launch, the pilot turned back into wind and the winch driver gave him a further launch, when the performance was repeated. This of course required very considerable energy and co-operation between the winch driver and pilot, but the technique had not been developed at this stage and the existing winch was not suitable. The idea, however, may have possibilities for the experienced pilot when using proper equipment.

Before dealing with the aero-towed launch, mention should be made of the system of launching round pulleys, where there is not adequate ground distance for the normal straight launch. The pulley can be used on auto-tows, winch launches, and on auto-bungey launches only when a 40-yard length of cable is inserted between the bungey and the glider, so that the former will not have to go through the pulley block. The main disdisadvantage lies with the fact that it is essential that a member of the launching crew should be stationed at the pulley block during all launches by any of the above methods, with adequate means of severing the cable in an emergency. This may be difficult as the pulley must have sufficient range of movement to enable it to align itself with the changing angle of the cable during the launch, and the guillotine, chopping block, or whatever other device is used, must be between the pulley and the glider, and never between the pulley and the winch.

Aero-Towing

Aero-towing is an excellent method of getting sailplanes into the air. Machines can be towed safely and to any suitable height or region desired by the sailplane pilot. The main disadvantage is cost.

The most satisfactory way for the normal club or group to obtain aero-towing facilities, is to charter a machine and pilot for the day from some well-known commercial concern. If it is desired to keep a towing aeroplane as part of the gliding club's normal assets, to be used for no other purpose, it will be a source of continuous expense and trouble. If one machine only is owned, it will often be off service due to regulation overhauls, etc., or suitable pilots may not be available to fly it.

The technique of aero-towing under normal conditions is both safe and simple. Pupils can be given their first aero-tows in calm conditions as soon as they can safely fly an ordinary circuit.

The towing cable used is usually about 300′ long, and is attached by a quick release at each end, and an additional weak link at the glider end, although some clubs prefer a weak link, of different strengths, at both ends. The aeroplane straightens out the cable and on receipt of the 'Full Ahead' signal from the glider proceeds on its take off run.

The glider takes off quite quickly, as its flying speed is normally much less than that of the aeroplane. It should climb to a height of 6–10 feet, so that it is both out of the slipstream and causing as little extra drag as possible to the aeroplane (Fig. 15). It should maintain this position throughout the flight, and this can be checked by seeing that the cable curves down slightly from the glider and enters the aeroplane lying parallel to

Fig. 15. *Avro 504n shortly after take-off with Cambridge sailplane on tow.*

its thrust line (*see* Diag. 2). If the sailplane gets too high above the aeroplane it will tend to pull up its tail and prevent it climbing. If the sailplane gets below the towing aircraft, it will pull down its tail and may even cause it to stall. As the best towing speed of the normal club sailplane is not often much more than 10-15 m.p.h. above the stalling speed of the aeroplane, this does not leave much margin for error, but apart from this, bad positioning puts a strain on both machines.

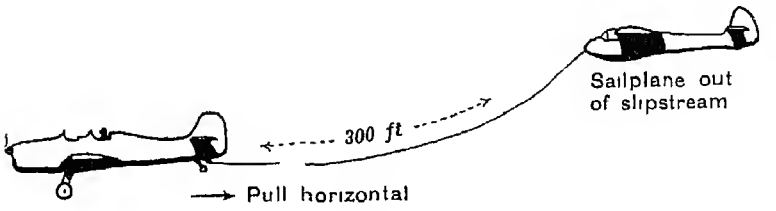


Diagram 2

Accurate positioning, however, in calm conditions presents no real difficulties.

Turns made by the towing aeroplane should be of a wide radius, and the sailplane should always turn slightly outside the path taken by the aeroplane, otherwise it may start catching up on the aeroplane and slack will develop in the towing cable.

On gusty or strong thermal days, aero-towing requires more care. On entering a patch of rising air the heavier aeroplane will bump and gain a little height, but the sailplane which is very much lighter may rise considerably and get into a position well above the aeroplane. Any attempt to dive down to the original position will only result in the sailplane catching up on the aeroplane and producing a large amount of slack in the cable, which is consequently taken up with a violent jerk at a moment when the sailplane is decelerating.

Most pilots have their own methods of overcoming this disproportionate gain in height, and one satisfactory method is to crab or sideslip slightly as soon as the aeroplane is seen to enter a bump or thermal. This puts extra drag on the sailplane and the nose can be lowered without much gain in speed as soon as the sailplane follows into the lift. Spoilers or flaps can sometimes be used carefully to prevent the sailplane overrunning the aeroplane.

If the sailplane does get too high the pilot can sideslip off the surplus height, which will prevent catching up further on the aeroplane, but the sailplane should never be left in a crab or slipping position at the moment the cable jerks taut.

Once in the air the sailplane pilot should act on any signals from the aeroplane, and should release at once if requested, however inconvenient it may seem: he is far better off than the aeroplane pilot when it comes to forced landings. The aeroplane pilot should make absolutely certain that the sailplane pilot has acted on his orders, especially as regards releasing. Accidents have been caused by the aeroplane pilot giving the signal to the sailplane to release, and then diving away without any check, when the sailplane's release had jammed. The sailplane was pulled down after the aeroplane, which was then unable to pull out of its dive due to the up-load on its tail. Proper releases, and weak links, should eliminate this danger, but it is easy for an aeroplane pilot who has been towing machines up all day to get tired and a little careless, even to towing the machine into cloud, which is not very helpful to the beginner. The aeroplane pilot should avoid losing height at any time with the sailplane on tow unless it is fitted with powerful spoilers or dive brakes, as this will at once cause it to over-run.

As mentioned earlier, the ideal position for the release for aero-towing is in the nose of the machine on the thrust line. If the quick release is the one used for winching, usually below the thrust line, the machine may tend to ride high, necessitating a continual forward pressure on the stick. This may be tiring on long tows unless elevator trimmers are fitted.

If multiple towing is contemplated, each pilot should have clear instructions from the towing pilot before-hand, as multiple towing is very much of a team job.

Whether a Y or V cable is used the sailplanes have to keep apart by the continuous application of the required rudder, and have the job of watching each other for position in addition to the aeroplane. If one sailplane should release or break away, the remaining machine(s) should re-adjust their positions so that the tow is balanced; if the tow is to consist of more than two sailplanes the manner in which they shall release or re-position should be decided beforehand.

One of the great advantages of aero-towing is that the sail-

plane pilot can actually 'see' a thermal, and can, therefore, be sure of releasing in rising air. When the aeroplane ahead of him enters an up-current it will bob up like a float, and, when a few seconds later his own machine follows suit, the sailplane pilot can immediately release, and start to circle.

Signals

Some mention ought to be made here on the subject of launching signals. There is often little attempt at standardisation in this respect, and pilots flying on strange sites may become confused at the local variety. Some form of standardisation is necessary and this system should use the simplest equipment possible.

Signals for launching purposes can be divided into two classes, verbal or close range signals, and distance signals when a visual type is necessary.

Verbal signals are all that are required for bungey launching, and the 'Walk', 'Run', 'Let go', shouts are well enough known.

For auto-towing, winching, and aero-towing, visual signals are required and the same ones can be used for all these types of launch.

A simple method which is widely used, is for the signaller at the sailplane to have two bats, or flags. Flags are more satisfactory as although they may wrap themselves round the sticks on occasions, they are lighter to use, and are not affected by strong winds like bats. They should be big enough to see clearly at half a mile, and be of contrasting colour to the background, *i.e.* white or yellow if the surroundings are mainly grass, hedges or woods, etc., and red if sandy.

The signals are four in number: (1) To indicate to the winch that the machine is ready to be launched—one flag held up stationary. (2) To indicate that the winch is required to take up slack in the cable—one flag moved slowly up and down. (3) To indicate that the machine is now ready to be taken off —both flags moved up and down. (4) Stop—both flags held up stationary. An alternative method is to use only one flag —moved slowly up and down for (2) and rapidly for (3) (Figs. 16 and 17) with no signal for (1), the sailplane held with the wings level being enough.

These signals should be answered from the winch end in

like manner for training launches when the instructor is at the sailplane end, but this is not necessary if the instructor is also the winch driver, or for ordinary sailplane launches with

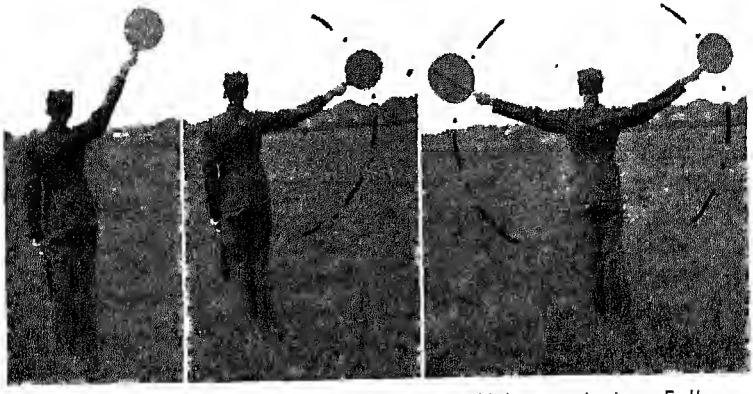


Fig. 16. *Signals for winch launch: Ready — Take up slack — Full out.*

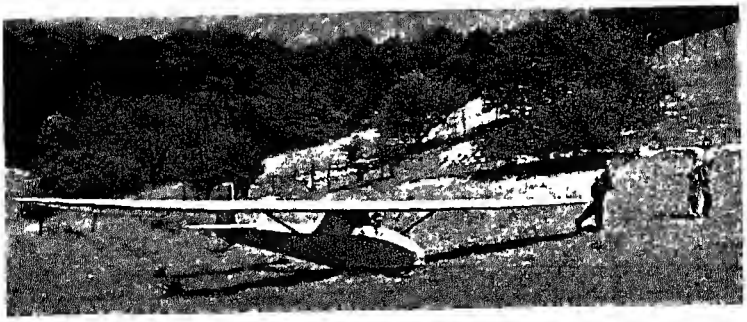


Fig. 17. *G.B.II sailplane at start of winch launch. Signaller is using one flag only.*

experienced pilots. The winch should always indicate however, by one stationary flag, if it is ready to give launches with the crew in attendance; the flag being taken down if the winch develops mechanical trouble or cannot give an immediate launch for other reasons. This will save the sailplane signaller a great deal of energy, and allow the pilot to remove the air of hopeful expectancy from his face; while people potter about with spanners, or petrol half a mile away.

Signals can also be satisfactorily made by Aldis lamp.

There is one further point that should be included in this chapter, and that is the question of earthing. In very thundery conditions all launches, except by bungey, should be suspended. If conditions are not severe, auto and winch launches can be carried on provided the car or winch is adequately earthed. An ordinary earth rod attached to a wire from the main chassis is good enough for the winch, but this cannot be used by a mobile towing car. A good substitute is a length of heavy chain attached to the main chassis and dragged along. It should be of sufficient length for at least part of it to remain on the ground when the car is being driven fast over rough ground. Aero-towing should be suspended if conditions are at all doubtful.

Chapter 3

INSTRUCTIONAL METHODS

INSTRUCTION in the art of flying an aeroplane was first thoroughly developed during the 1914–1918 war, when it was necessary for pupils to reach a certain standard efficiency in the minimum time. From this basis instruction has been further modified to suit changing service and civilian requirements and to keep pace with modern aircraft. Before the last war however, there was no standard method of instruction, each school teaching according to its own ideas. This was the best thing possible at the time, as many systems were thereby tried out, so that when standardisation became necessary to ensure that every pupil was adequately trained, there was a wealth of material available to work from. In case it may be thought that this experimentation with pupils was hard on those who paid cash to be taught, let it be said that an honest private concern using its own, and usually limited, capital, could be relied upon to give the very best value possible where risks were concerned.

When gliding was restarted here in 1930, the continental method of bungey launched Solo Training was introduced. This method, however, was not well suited to British ideas, and soon each club was developing its own variation of Solo Training. As has been mentioned before, hand bungey launching gave way to mechanical auto-bungey launches, auto-towing, and winching. A few clubs also started to experiment in detail with the idea of dual training. It will be seen, therefore, that although clubs in Britain at any rate were diverging from the existing German methods, much valuable experience was being gained for such time as standardisation of instruction would become necessary in this country. Immediately before the war there were enough people interested in gliding circulating between the clubs, to require this.

The first method, which follows, gives an idea of Solo Training using a winch. The patter is that developed by one particular club, but the sequence of instruction is general. In America and elsewhere there has been some development in Dual Training.

The use of military gliders was developed during the late war to a tremendous extent, with its own concentrated method of instruction. This is unsuited to civilian requirements, and it is not proposed to go into this separate subject here.

Fig. 18. *The instructor (H. E. Hervey) explains the effect of the elevator to a pupil undergoing his primary training.*

Method II, which also follows, discusses the problem of dual training, based on experience in its use in the U.S. and here, but before dealing with these two methods, a few words may be said on the subject of the Instructor.

The Instructor

The desired qualities for the aeroplane instructor are well enough known and a great deal has been written about them. The gliding club instructor (Fig. 18) is, however, a slightly different being, although this does not mean that either should not succeed at the other's job.

Gliding clubs are seldom profit-making concerns, and cannot usually pay much in the way of instructors' salaries. This has led, in time, to a number of amateur instructors being gradually collected around one, or rarely more, professional instructors, or in some cases even a Chief Amateur. This system has worked well in the past, as clubs have been small concerns, jealous of their reputation for efficiency and safety.

Gliding instructors may be divided into two categories; those who instruct in two-seaters, and those who instruct from the ground, when training is carried out solo.

The first type should be a good pilot with experience, and a good instructor. He must be able to impart his knowledge clearly to the pupil and at all times inspire him with confidence. The second type need not be a particularly experienced pilot, although he should at least be able to fly safely and tidily, but he should be a first-class instructor, absolutely clear in his own mind as to what he intends to do, and able to impart the necessary knowledge in the fewest possible words. He should have considerable experience as a winch or tow-car driver. Quite often pilots of comparatively little experience make good assistant Solo Instructors as they still remember their own early difficulties. Obviously, when the pupil must rely on himself entirely throughout the flight, the instructions beforehand need to be as clear and simple as possible; no pupil is in a position to sort out obscure meanings when the ground is rapidly approaching and he only knows that there is something wrong somewhere.

The instructor who is training solo needs also to be more of a psychologist than the dual instructor, although this quality is obviously of great benefit to the latter. Some pupils are easy

to deal with and go through their training smoothly; others require a great deal of thought. Maybe there is just one thing they cannot grasp, or perhaps they are very under-confident, or over-confident. Some pupils get fixed ideas over some little point, and others cannot make up their minds. These difficulties are easier to deal with when the instructor is in the machine with the pupil, than when he is on the ground and unable to influence him directly. Such occasions sometimes call for fairly drastic measures on the instructor's part, but measures that he can only take when he is absolutely sure of his diagnosis of the pupil's troubles. Again, some action seemingly drastic to the pupil is all right when the instructor is on board, but when he is on the ground there must be no mistake in his action.

Whether the instructor is training dual or solo, he should always be asking himself, "WHY does the pupil do it this way? Is it basic in his make-up, or is it just an acquired habit?" Everyone does things differently, and an instructor should never attempt to alter a pupil's basic method of action and train of thought: if he does so, he will inevitably leave the pupil without any. He should try to find out which way round the pupil naturally does things and adapt his instructions accordingly. Obviously this should not consist of letting the pupil have things all his own way, and, in some cases where the pupil seems to have no ideas at all, it is essential that the instructor should firmly implant a suitable method into the pupil's head.

If an instructor has continuous difficulty with a pupil, he should make certain that the fault is not his own before turning him down. Sometimes two people's temperaments just do not fit, and although in most cases this becomes apparent early on, sometimes it does not, especially if the pupil is keen, and willing to hide any feelings in his desire to get on. If difficulties seem to be developing between instructor and pupil, or if the pupil seems slow and stupid, he should be handed over to another instructor before a deadlock has been reached. Circumstances will decide whether the pupil should be told why the change is taking place or not.

All the time the instructor has a pupil in his charge he should not only be correcting errors which become apparent, but watching out for potential faults which may not develop until sometime after the pupil has left the instructor's direct

care. For example; if a pupil is a naturally good pilot and has plenty of confidence as well, he may later get into trouble through being just too clever. In this case it will probably pay the instructor to let him frighten himself while still under his direct control.

There is another range of difficulties which the instructor will have to watch out for, and these are caused by physical defects or habits, and consist of such things as left-handedness; one leg longer than the other, causing unconscious use of rudder; dislike of being out of a normal position in the air, resulting in flat skiddy turns, and so on. Any tendency in these directions should be eradicated at once before they form habits which may spoil a pilot's flying perhaps for years.

Instruction in the art of flying is a very skilled undertaking and certainly not a job to be entrusted to anyone just willing to do it. A bad instructor may ruin for ever a pupil's ability to become a good pilot, and a good instructor will be the first to realise that he can never accumulate enough experience.

The Instructor should strive to obtain the very best from his pupils. It is not enough to produce merely a safe and adequate pilot, or be able to say, "Oh, so-and-so is all right". He should be always using his knowledge and critical eye to assist the pilot to develop his technique, and give to his flying that polish which immediately marks the first-rate pilot (Fig. 19).

With regard to Instruments. As soon as the pilot can make a safe circuit on a secondary, or on any dual trainers, and has ceased to subject his machine to continuous rough usage, it is a good idea to fit a variometer, as this instrument should be used instinctively like a sixth sense. An altimeter can be usefully fitted at all times, but an A.S.I. is not essential, nor in the author's opinion, advisable until the pupil is practising really accurate circling in thermals, or is flying a closed machine. Glider and sailplane flying is so much a question of the development of accurate feel, and is very different to the flying of a modern aeroplane.

METHOD ONE — *Solo Training*. Launching by Winch.

It has been found satisfactory both from the instructors and pupils point of view to divide the training up into definite

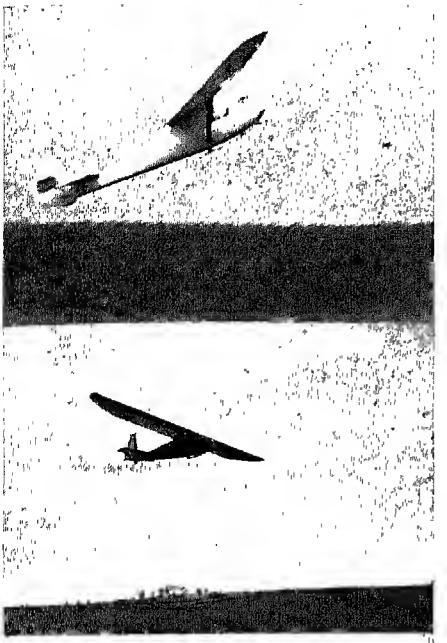
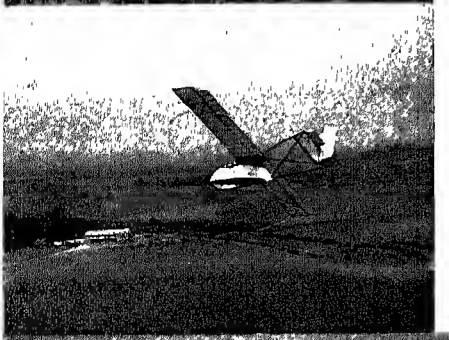


Fig. 19. *As the instructor sees them.*

(a) Start of winch climb (Cambridge II). This steep angle is all right for the pilot of experience who knows his machine, but should be discouroged in the pupil.

(b) Hill soaring in a strong wind (Desoutter G.B.I) machine facing almost into wind, and keeping well out over hill face.



(c) Pupil turning in Nacelle Primary. The nose is well down, but although enough bank to come out of the turn has been applied, there is still a certain amount of right rudder being used, showing slowness in co-ordination.

(d) Coming in too slowly over obstructions (G.B.II), to be strongly discouraged in all club flying. Note slowness of controls to react.

stages, in order that no part shall be inadvertently left out, due perhaps to the pupil having been absent for several weeks.

The stages are as follows:

Stage 0. Pre-flight instruction.
1. Groundslides.
2. Airborne slides.
3. Straights at X ft.
4. Climb and release (plus Appendix 1 Stalls, Spins and corrections).
5. "A" certificate straights.
6. Turns (plus Appendix 2 Drift landings).
7. Circuits (plus Appendix 3 Steep turns).
8. Sideslips.
9. Elementary soaring.

The following patter is not intended to be used word for word, provided the necessary points are made clearly to the pupil. The principle on which this method is based, is to give the pupil as much chance as possible to use and develop his initiative and skill (or lack of it) under safe supervision. The psychology of each instructor and each pupil is different, and this variable factor makes it impossible to produce any one patter to suit all cases.

Pre-flight Instruction — Use of Controls

Instructors' Notes

The pupil should thoroughly understand the use of controls before sent on his first ground slide, and should have had enough stationary practice with the instructor to enable him to operate the stick and rudder automatically.

It is advisable to give this instruction with the pupil in the seat as he will be when actually flying, as then control movements can be demonstrated with less talk.

A pupil should be given as little theory as possible in the early stages to avoid muddling him.

Patter

On a glider there are three controls, two operated with the stick by hand, and one by the feet.

The control which you must get to know first is the rudder, which is the vertical surface on the tail and which is operated by the feet with the rudder bar (or pedals). The object of the rudder is to enable you to keep straight directionally, or to turn. For left turn press left foot. For right turn, right foot.

Therefore, if the machine is turning away to the right and you want to turn back again to the left, you press left foot.

The ailerons are the control surfaces on the wings and are operated by side-to-side movements of the control column.

They are necessary in order to keep the machine laterally on an even keel or to bank it.

To bank over to the left, put the stick to the left; and for right bank, right stick. An easy way to remember this is to always try and keep yourself upright; if the left wing drops, then lean to the right and bring the stick over with you.

The elevators are the horizontal surfaces on the tailplane, their object is to enable the machine to be flown faster or slower.

If you move the stick back towards you, the nose will rise and the machine fly slower and finally stall.

If you put the stick forward, the nose will drop and you will fly faster.

But you will not use this control until you have done a few slides.

Practice

The instructor should stand on one wingtip, holding the wings level while giving patter on use of controls.

When the pupil seems certain of the uses of the stick and rudder, the instructor should move the wings fairly rapidly up and down, and turn the machine from side to side with the pupil trying to correct these movements. In a strong wind it is of benefit to the pupil to allow him to keep the machine balanced by use of the controls alone.

He should be encouraged to look as far ahead as possible *all* the time. He should also be encouraged, at this stage, to make very definite movements with the stick and rudder.

When the instructor is satisfied that the pupil is quite clear

as to what he has to do, he should be given his first ground slide as soon afterwards as possible.

STAGE 1 — GROUNDSLIDES

Instructor's Notes

At least four slides should be given before the pupil is permitted to leave the ground, to make certain that he is really sure of what he is doing. The wind should not be strong.

Fig. 20. *Pupil ready for ground slide. Note stick held forward while arm rests on knee for steadiness. Also tight harness for the same reason.*

It is sometimes the practice to tether the stick fully forward, or only allow it to have a very small range of movement during the early training stages.* Although it can always be said that this habit has prevented crashes, it will be found that the pilot

* The A.T.C. have developed this method, and two-way winching to a high degree, and find it very successful for their purposes.

develops far more quickly a sense of responsibility in the air when he is allowed full movement of the elevator at all times, and is allowed to find out their power by gradual experimentation, assisted by clear tuition, and the strict supervision possible with winch launch training (Fig. 20).

Until stage four is reached it is essential that the winch cable shall be securely attached to the glider, so that the winch driver will have full control over the machine.

Patter

Hold the stick hard forward and try to keep your wings level while moving straight to the winch: make any corrections as early as you can. Look as far ahead as possible and, if you want to, hold the seat with your left hand to steady yourself. Never put your feet on the ground until the cable is disconnected, or the winch engine is stopped. You will be more comfortable if the harness is done up tightly.

Winch Driver's Notes

Winch to be driven just at flying speed of aircraft, making allowances for wind strength.

Try to keep cable straight and not curving out to one side; violent swinging of the machine can be checked by slowing down engine as the swing starts and picking up as the nose passes centre on the following reverse swing.

If swinging gets really bad, it is advisable to stop entirely, or slow right down, until all traces of it have stopped, and then gently pick up speed again. Be certain that the wing will not get damaged if on the ground, and the pilot has not put his feet down.

Checks for flying speed of the aircraft:

(1) If the tailplane is visible above the wings (Dagling Primary) during a slide on level ground, then the speed is too *high*.

(2) If the ailerons seem very slow in functioning and one wing remains low although that aileron is down, then the speed is not great enough.

ALWAYS MAKE CERTAIN WHO IS IN THE MACHINE BEFORE LAUNCHING.

Never give a first slide unless certain that the pupil has been given the necessary pre-flight instruction.

Stage 2 — Airborne Slides

Instructor's Notes

This stage can be commenced as soon as the pupil is good at slides, even after his fourth run.

Patter

This time you will be able to try the elevator control; when the stick is eased back the nose rises, and when put forward the nose drops.

It is a more sensitive control than either the rudder or ailerons.

On your next run, start off with a *slide* in the usual way, and when going absolutely straight, ease the stick back a little and wait. If nothing happens, ease it back a little more and wait again. Go on gently like this until the machine leaves the ground.

If the stick is pulled back too much at first the machine will suddenly shoot up in the air, so be as gentle as possible with it.

Having got off the ground, wait again. If the machine seems to be getting higher and higher, then ease the stick forward very gently.

If the machine drops back on the ground again immediately, then the stick may need to come farther back.

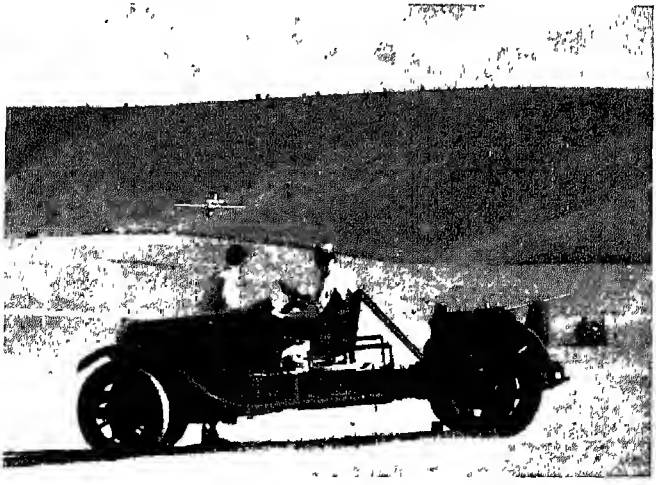


Fig. 21. *Primary glider being winch-launched at "low hop" stage.*

Try and fly along, keeping just off the ground and not forgetting to still use the other controls as well (Figs. 21 and 22).

If you get too high DON'T try to dive back on to the ground or put the stick forward at all fiercely. The winch driver can always bring you down safely if you get too high, but cannot stop you diving into the ground.

Try to avoid pump-handling with the stick, and *look well ahead.*

If you don't manage to get off the ground at the first attempt, it does not matter, you can do so next time, and you will have learnt something about the elevator. On the other hand, remember that on these early hops you will get just as much experience flying at 6 inches as you will at 6 feet.

Winch Driver's Notes

Winch to be driven at flying speed of aircraft.

Be ready to correct for height and direction.

If the machine gets too high, decrease speed a little until the machine is sinking gently on an even keel. Then at required height, give enough speed to continue the flight or to land the machine.

On no account allow slack to develop in the cable, as this will delay the pick up.

Nothing can effectively be done to stop the machine diving to the ground. A decrease in speed, however, tends to make the elevator controls less fierce.

Stage 3 — Straights at X Feet

Instructor's Notes

Only in calm or light winds. Make certain the pupil is not flying towards low sun or in dazzling conditions. The object of these straights is to acquire judgment of height by endeavouring to fly at a constant pre-determined height.

Patter

Put stick a little forward of central before starting. Take machine off ground by easing stick back and climb to X feet (5, 10, 15, 20) and level off by easing stick gently forward until machine is no longer gaining height; look well ahead and try

to fly straight at winch, correcting with a little rudder for any side wind or drift. Avoid pump-handling and try to remain at same height. When power is shut off ease down into a definite glide, (the machine flies at a considerable angle of incidence when given power by the winch and will stall if left in this attitude when winch stops) until time to flatten out for landing. During landing especially, look as far ahead as possible, and never down at the ground below.

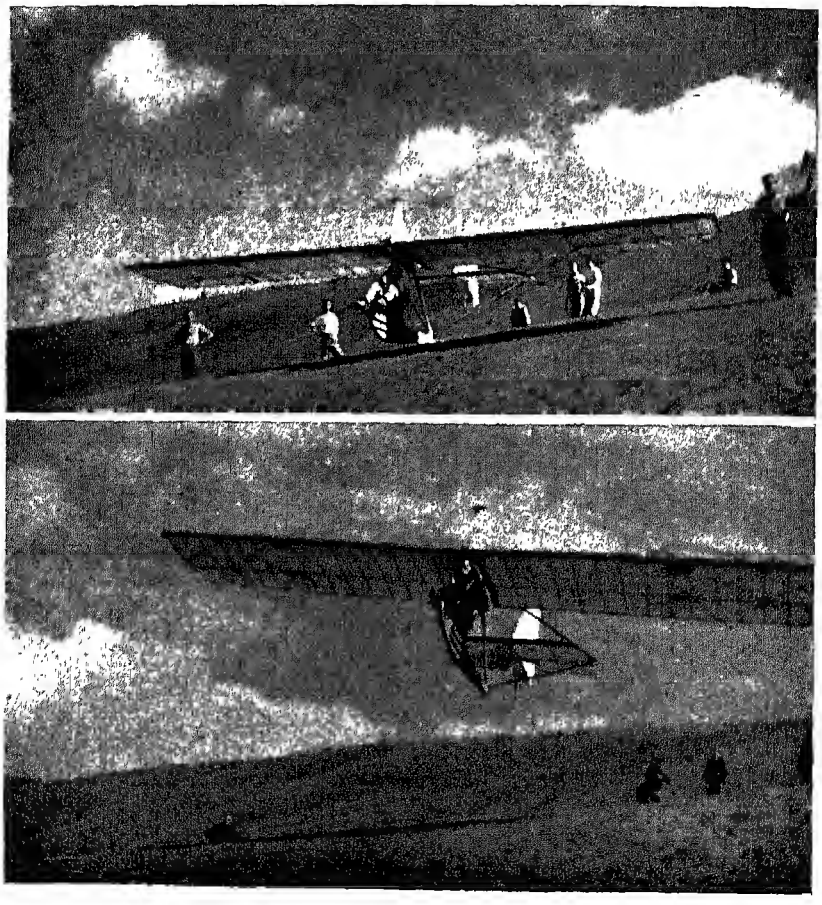


Fig. 22. *Auto-launched low hops on Primary glider. (a) Shows correct attitude and steady take-off. (b) Indicates over-controlled and untidy start, although pilot corrected without delay.*

If the approach is made without drift and at correct airspeed, landing a glider or sailplane is not difficult. The touchdown attitude is not much different from the normal flying attitude, the control column just being eased back enough to make contact with the ground smooth, and not abrupt.

Winch Driver's Notes

Still correct for height and direction. At the end of the straight part of the flight, cut down power sharply so that pilot will notice the change, but keep the cable from developing slack, in order to correct any faults.

STAGE 4 — CLIMB AND RELEASE

Instructor's Notes

The information in Appendix 1, on Stalls, should be given to the pupil before commencing.

The main purpose at this stage is to obtain practice in finding correct gliding angle.

Patter

Ease the machine off the ground and climb gently to the required height. When the power is shut off, put the nose down *at once* and adjust for the best gliding speed.

Good indications for this are the feel of the wind on your face, which should be like a fresh steady breeze, and a firm feel in the controls. Land as before.

Remember, that the steeper the climb on the winch, the greater the alteration that will be necessary in the attitude of the machine before being able to attain the correct angle of glide.

Winch Driver's Notes

It is advisable to still keep the cable attached for the first few flights, until the pupil is able to estimate his gliding speed with reasonable accuracy. There should, however, be no tension in the wire, although no slack should be allowed to develop in case a burst of engine power is required to check a stall, or give the machine enough speed to land safely.

The above flights should be followed by a few medium-high flights (50-60 ft.), when the pupil should be allowed to release the cable himself.

Stage 5 — "A" Certificate Straight Flights

Instructor's Notes

These flights may be made on either the Primary or Secondary type of glider: the Secondary will be found more satisfactory, as the slightly better gliding angle will make the attainment of the required thirty seconds easier.

Patter

This time, take off as soon as possible and climb steeper than usual. If you are climbing too steeply, you will find the machine has a tendency to buck fore and aft. Stop this by easing the stick forward slightly. As soon as the winch stops, get the nose down, glide as usual and land.

Winch Driver's Notes

Take machine off as usual and take it up as high as possible, remembering the length of field, and that pilot will be worried and may do something rash if flying towards a fence or obstruction.

It is advisable to give a small burst of power just before stopping the winch in order that the pupil will have plenty of speed in case he is slow in getting the nose down.

Stage 6 — Turns

Instructor's Notes

It is quite a good thing to ask the pupil first of all how he would do a turn. He will invariably say put on rudder and stick to same side. It is better that the pupil should put on bank first and rudder immediately after, and only a little of each.

It is essential to make clear to the pupil that a correct turn on a glider is not a flat one. The amount of bank needed is relative to the speed. An aeroplane needs to bank more, as the speed is greater. The speed of a glider is low, so the bank required is little. It is, however, a correctly banked turn.

The information in Appendix 2 should be given at this stage.

Patter

As soon as the gliding speed has been checked after releasing the cable, try a gentle left turn. Bank to the left and put on enough rudder to make the nose of the machine travel sideways across the horizon.

Almost immediately, correct, and then do the same to the right. Correct and glide straight towards the winch before landing, from a height of at least 20 feet.

Do not continue your turns more than 20 or 30 degrees away from your normal straight path, otherwise you may not leave yourself enough height to complete the flight properly.

Remember, rudder alone makes the machine skid outwards, and you will get a draught on your face from the *outside* of the turn.

Bank alone will make the machine slip inwards and you will get a draught on your face from the *inside* of the turn. In neither case will you be comfortable in your seat.

It is very easy to lose speed on a turn so make certain of having plenty before starting.

Winch Driver's Notes

As for Stage 5 flights. It is not advisable to take the machine higher than previously in case the pilot just doesn't do any turns, due to some reason best known to himself.

STAGE 7 — CIRCUITS. B STAGE

Instructor's Notes

It will probably be found better to give a really high launch for a full circuit, after practice in the gentle turns on otherwise straight flights, so that the pilot has more time to correct, and judge his first real approach than he would have if he was lower and making only a U-shaped flight. Appendix 3 (Steep Turns) should be brought in here.

Patter

First of all climb as high as possible and do *not* release until the winch driver stops the winch (Fig. 23).

If the machine starts bucking during the launch, ease the nose down slightly.

As soon as you have released—and do NOT forget this—adjust for correct gliding angle and then start the first turn as soon as possible (point out local positions), and always turn outwards away from the hill (if any).

Having got round the turn (180°) remember you are now flying down wind and therefore your *apparent* speed will be

Fig. 23. *Kite climbing well on full winch launch.*

greater, due to the ground speed being higher, so do not be misled and stall.

While still flying down wind, work out the approach; if you are low, get on with the next turn round into wind again. If you find that you cannot get right round again, don't try. Make about 20 ft. the minimum height ever at which to be turning. Then level out and land straight ahead.

If you are still high, wait a bit before turning round into wind, but it is always better to come in slightly high and then do gentle S turns into wind, than undershoot.

For the B flight test (left and right turns — 1 minute). Make a left turn as usual off the launch, continuing it so that you cross over the launching track, and then make a right-hand turn round into wind again. (Denote turning points over the field).

Winch Driver's Note

Full launch, stopping winch when machine is as high up as possible, consistent with safety. (*See* first sentence in patter, above).

STAGE 8 — SIDESLIPS

Instructor's Note

As there is frequently a gap between the B flights and the necessary soaring weather for the C test, it is a good thing to give the pupil some sort of practice or qualifying flights to

do. It has been found advisable to practice sideslips on a secondary such as a Cadet or Grunau type, as the Primary has too rapid a sink for safety.

Patter

The object of a sideslip is to lose height quickly without gain in forward speed.

Climb up as for a circuit and turn on to the down wind leg as soon as possible, and (if it is a left-hand circuit) try a left-hand sideslip.

To do this put on left bank and then enough right rudder to prevent the nose travelling to the left. To correct, centralise all controls, and then continue the circuit by turning into wind. If you still have enough height try the same thing again before landing, but coming out at least twenty feet up. Remember, that in a sideslip one wing will be down and may be nearer the ground than you think.

If at any time in the slip the speed seems excessive ease the stick back slightly, remembering to let it go forward when levelling out.

Never slip away from the landing ground.

Winch Driver's Note

Full launch as usual.

STAGE 9 — "C" FLIGHT (FIVE MINUTES' SOARING)

Instructor's Notes

Secondary or Utility type sailplane recommended. The notes and patter for these flights must depend to a large extent on local conditions, and should be adapted as necessary. A normal hill site, with landing field at the foot, has been assumed here, as this is not an easy combination for early soaring flights due to the double turn usually necessary before making safe connection with the hill lift.

Weather conditions should be carefully chosen for this flight, the wind being steady, with little thermal activity, for preference.

Patter

Take off into wind, and after releasing turn back towards the hill, and almost at once turn again along the hill. You will

have to make this second turn much earlier than you expect, as the wind will otherwise drift you over the hilltop, and into the downdraught behind. Fly straight along the ridge until you have settled down, and then turn outwards from the hill, and fly back again along the same path until you reach point X (local point). Then turn again and fly back, etc.

Remember that the wind is continually trying to drift you back over the hill, so you always want to keep the machine facing slightly up wind. Secondly, remember that there is often a tendency to fly progressively slower and slower on a first soaring flight.

When it is time to come down, fly out from the hill on to the usual circuit, which you may have to make wider than normal if you have increased height. Then land as usual. BUT, if at any time you get too low, come down and do not try to soar by pulling the stick back because it is impossible. If you are not comfortable in any way, come down; you can always try again later.

Winch Driver's Note

Full launch.

* * * * * * *

If C flights are to be made by soaring in thermal upcurrents due to the absence of a hill, the pupil should practise circling straight off a good winch launch, and should, to begin with, be given a minimum height below which he may not start, or continue, to search around for lift.

Following on the first soaring flight, the pupil should be given every opportunity to make further such flights under supervision: the instructor allowing him longer time in the air, an extended beat along the hill, and practice in flying in less easy weather conditions, as he thinks fit.

Appendix 1 — Stalls, Spins and Corrections

A stall occurs when the aircraft flies too slowly and loses flying speed (rather as a sailing boat loses way and becomes uncontrollable).

N.B. A model should be used to demonstrate.

Different machines have different stalling speeds. On primaries the stalling speed is low, about 25 m.p.h. The following applies to trainers.

(1) If the machine is stalled very gently and straight it may just sink on an even keel like a parachute.

(2) If it is stalled sharply, but straight, the nose will drop, and as soon as the machine gains enough forward speed by gravity it can be pulled out of the dive, unless the ground is reached first.

(3) If the machine is stalled with rudder on, or if a turn is attempted when nearly stalled, a spin may result. The nose drops sharply and the turning motion continues. To get out, put on full opposite rudder, move the stick forward, and when the turn stops pull out of the dive.

So very little speed is needed to regain control that, provided the spin is stopped, the nose will come up almost at once.

The machine should be put into the normal gliding attitude immediately the nose begins to rise, otherwise the glider may be stalled again.

Appendix 2 — Drift Landings

The following are three examples of drift landing corrections:

(1) Glider flying at 90° to wind; ground passing from left to right fast, the only way to correct drift when in this position is to bank slightly to the right, watching right wingtip for nearness to ground, and apply left rudder, in other words, sideslip into the wind, trying not to bounce on landing, as this will counteract the correcting sideslip of the machine.

(2) Glider flying almost into wind; ground moving left to right but fairly slowly. Apply as much bank as possible without

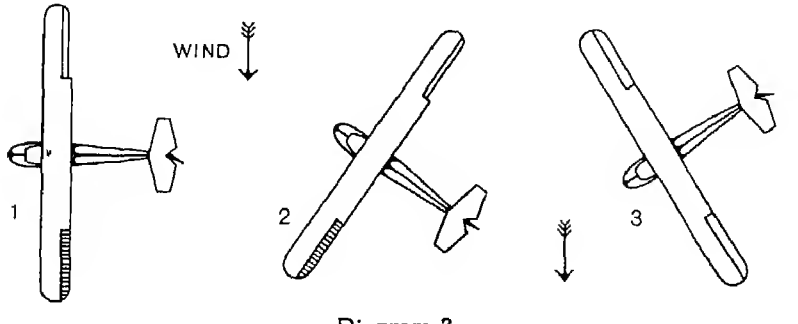


Diagram 3

the wing touching the ground, and very little or no rudder in the same direction. This will have effect of making a slipping-in turn into wind and, although the resultant landing may not look very pretty, it will be safe. If the wing just touches first it will probably not matter as the ground speed will be very low and the wing only moving at very little speed.

(3) Glider flying almost down wind; ground passing from left to right, speed over ground very fast; apply slight left rudder *only*, so that machine turns farther down-wind. (It is impossible to try and turn into wind at low height, and if any bank is applied with the rudder it will only make matters worse as the machine will be forced over sideways on to its left wingtip). It is very easy to stall when flying downwind near the ground as the apparent speed is still high.

Appendix 3 — Steep Turns

It is important to realise that whatever the position an aircraft may be in, the controls will always have the same effect. That is, the rudder will always make the nose move towards a wing-tip and the elevator cause the nose to move towards the pilot's head or feet. As the angle of bank in a turn is increased, the more will the elevators control the movement of the nose around the horizon and the less will they control the position of the nose above or below the horizon. Similarly, as the angle of bank is increased, the more will the rudder position the nose on the horizon and the less will it turn the nose around the horizon. This is most easily understood in the case of a vertical turn.

In a steep turn it is therefore necessary to keep a backward pressure on the stick and make little use of the rudder. Plenty of speed is essential, as the stalling speed is increased considerably.

Solo Training Advanced Instruction

By the time that the pupil has had enough practice to complete the above stages to the satisfaction of his instructor he will be ready to go on to his advanced training. He should have put in about five hours flying in medium performance sailplanes and developed a good sense of responsibility and independence in the air. All his flying will have been solo, and so he will be well practiced in assimilating his instructor's remarks before taking off.

Aero-Towing

Before really starting on the advanced stage of his instruction, the pupil should if possible obtain experience in aero-towed launches, which for normal purposes do not come into the advanced category.

Suitable calm weather should be chosen and the instructor's remarks before the flight might be along these lines.

"Keep straight behind the aeroplane, and as soon as you become airborne climb to about 6 to 10 feet so that you are causing the least drag to the aeroplane, so enabling it to get off more quickly, and are also out of its slipstream.

"Maintain this relative height throughout the flight; a good check is to keep the top of the aeroplane level with the horizon. When turning try to fly slightly outside the aeroplane's path so as to keep the towline taut (Fig. 24).

"If slack develops in the cable due to your getting too high, and you start to catch up on the aeroplane, slow yourself down by gently sideslipping or swishtailing with the rudder, but make absolutely certain that when the cable tightens up, as it will, maybe with a jerk, that the sailplane will get a straight pull and be in its normal flight position. Keep your eye on the cable and try to keep the tension even.

"Watch the tow pilot's signals and act on them immediately, and without question."

The pupil should then make about six aero-tows within a short time and under varying conditions, and with instructor's supervision.

The first stage in the advanced instruction will be the change over to, and practice in flying, a sailplane of higher performance, on which the pupil should obtain considerable practice in circling and use of the variometer.

Instrument Flying

This is necessary in advanced soaring, and training is obviously better done dual, either in a sailplane or at the local aeroplane club, although it can be, and has been, learnt solo in a sailplane.

If the pupil is absolutely unable to get any dual instruction, he should try to obtain practice on a link trainer and put the knowledge gained to use in the air stage by stage. Failing this,

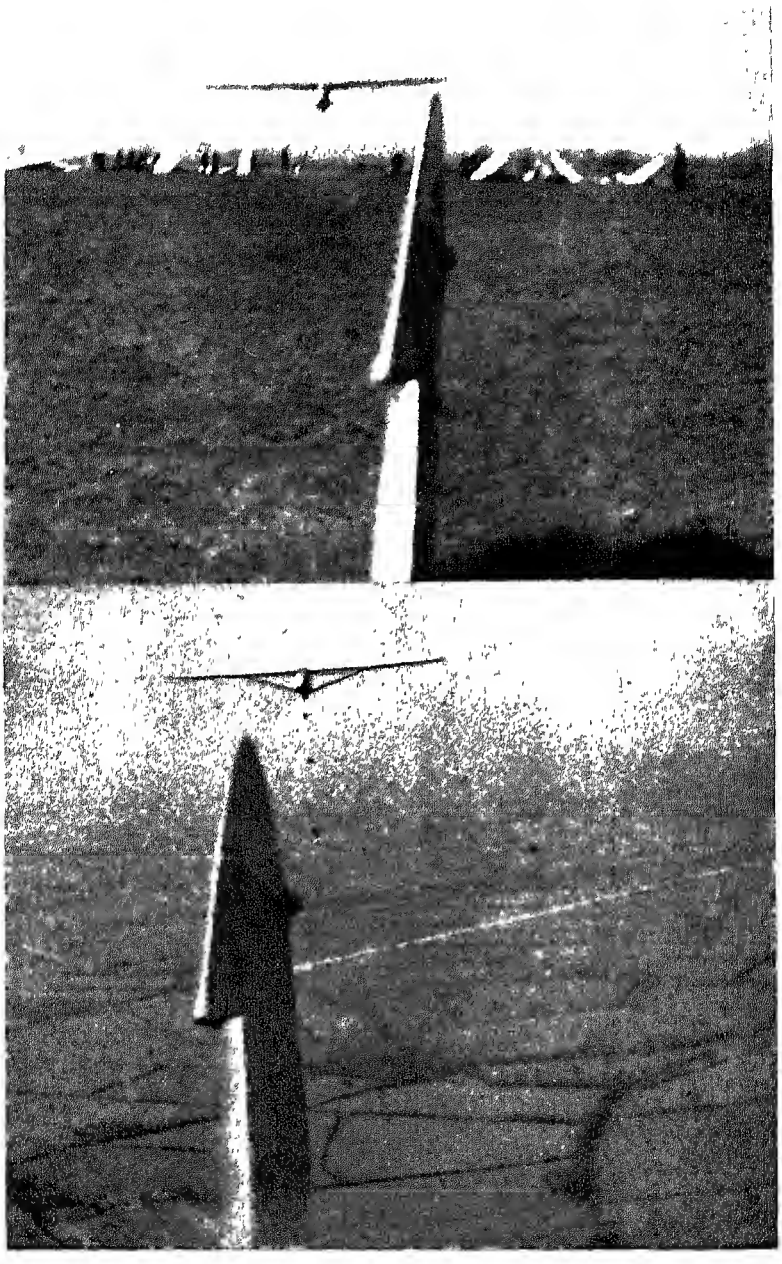


Fig. 24. *Camel (pilot J. S. Sproule) on aero-tow. (Plane pilot L. C. Withall). Showing (a) correct height of sailplane before aeroplane has become airborne and (b) when in air.*

he should study a recognised blind flying instructional manual, and with his instructor's co-operation and advice, put it into practice in the air by himself. If the pupil can only obtain one or two blind flights with an instructor, he should use these for spinning and practice, after he has learnt the use of his instruments. Solo blind flying training should never be attempted if there is any possibility of the formation of cumulo-nimbus.

If he decides to teach himself, the pupil should first of all get right away from the local flying area, and any other sailplanes, and be at least two thousand feet up.

First of all, the machine should be flown straight at the normal gliding speed, and the position of the turn, bank, and pitch indicators noticed; then rudder should be applied (in each direction) and the movement of the turn needle checked, as well as its behaviour when returning to straight flight. Similar experiments should be made with the air speed indicator and bank indicator, and should be made while the pilot can see his position relative to the ground.

The pupil should now put his head well down in the cockpit, and go through all the above movements again, resisting any temptation to 'cheat'. Corrections should ALWAYS be made in the same order: (1) Centralise turn indicator with rudder. (2) Correct pitch, or air speed, with the elevator. (3) Centralise bank needle, or bubble, with ailerons. This sequence of correction should be practiced until it is instinctive.

If *small* cumulus cloud is reached after this stage further practice can be obtained by flying straight through it, turning in clear air on the far side and then flying back through it again.

When he is happy at straight-and-level on instruments, some rate 1, 2 and 3 turns should be made in clear air, the pupil watching his instruments to see that the turn is kept constant, but also looking out, in order to get a picture of the size, and degree of bank, of each of these turns. He should then follow this by making similar turns with his head down in the cockpit, and entirely on instruments.

On straightening up after "blind" turns the pupil should resist the temptation to look out until he has overcome the sensation of going into an opposite turn on coming out of the first one: this is a very real feeling, and must be conquered.

The next step, and this is a vital one, should be to put the machine into a spin in clear air, but with the head down in the

cockpit watching instruments only. The machine should be brought out of the spin without looking out. This should be practiced several times in each direction, but the importance of keeping a check on height cannot be over-emphasised, nor the necessity for looking out for other aircraft before starting.

When it is first possible to practice turns and circles in actual cloud, the pupil should not be ambitious, but should come out into clear air after every seven or eight circles, even if this means losing the upcurrent; otherwise all he may acquire is a good fright, and add nothing to his skill, or confidence in his instruments. When he has become fairly confident, the pupil should circle up into a *small* cumulus for about 300 ft., put the machine into a spin and try to regain normal flight before coming out of the base of cloud again.

With a moderate degree of skill in blind flying it will be possible to use available conditions to better advantage when attempting the Silver C test flights for height and distance, but it should be stressed again that blind flying is better learned dual, and that only constant practice makes for safety under actual conditions.

Aerobatics

These can be learnt quite safely solo under the instructor's guidance. Further details will not be given here as they may be obtained from the many manuals dealing with aeroplane flying. The differences are that aerobatics are more limited on sailplanes, and that the extra speed necessary can be acquired only by diving.

Cross-country Flying

This will be dealt with fully under the appropriate chapter, but the usual fault of the beginner is to leave the site without sufficient height to allow of his safe return if the lift suddenly gives out, or even to give him a chance to search for further lift, before being forced to look hurriedly for somewhere to land.

If the pilot feels he is not high enough (about 2500-3000 ft. is a safe altitude) before being committed, he should leave the thermal and return to the site, especially if hill soaring is also possible. He may then still have some extra height in hand, and so be able to fly upwind of the site, and take advantage

of any thermals forming in this region; this would enable him to reach a greater height before drifting too far downwind to make any return to the site possible. It would also give him more time to look for further sources of lift.

Dual Training

Dual training on sailplanes is not dissimilar from dual training on aeroplanes, except that it will be found better to carry out the training more by example, and development of a sense of feel, than by the more logical instruction used for aeroplane pilots. Also, the flights are more limited, due to the nature of the sailplane.

As the training flights, even from 1000-ft. circuits, are likely to be of short duration, the machine used should have the best possible sinking speed and gliding angle, consistent with good handling and training characteristics. With the instructor on board who knows his job, there is no need for the pupil to learn in a machine of poor performance and consequent short flight duration.

The method discussed below is based on the work of several different organisations, and is therefore experimental and requires practical development and modification. It is, however, a basis from which to work, for clubs wishing to change over to this type of instruction.

The notes deal with the training of the pupil from his first experience in the air, through his elementary training, aerotowing, and conversion to advanced sailplanes. The method of launching is by winch.

Air Experience

Perhaps the most important of any stage of the pupil's instruction is the first one, usually described as 'Air Experience'. The flight should be carefully suited to the pupil's temperament as far as the instructor is able to judge it at this stage, and should err on the cautious (or dull), and short side. The instructor should never use this flight as a busman's holiday; many prospective pupils have not continued their training because they have had more than enough the first time they went up. Experienced pilots, who are absolutely instinctive in the air are

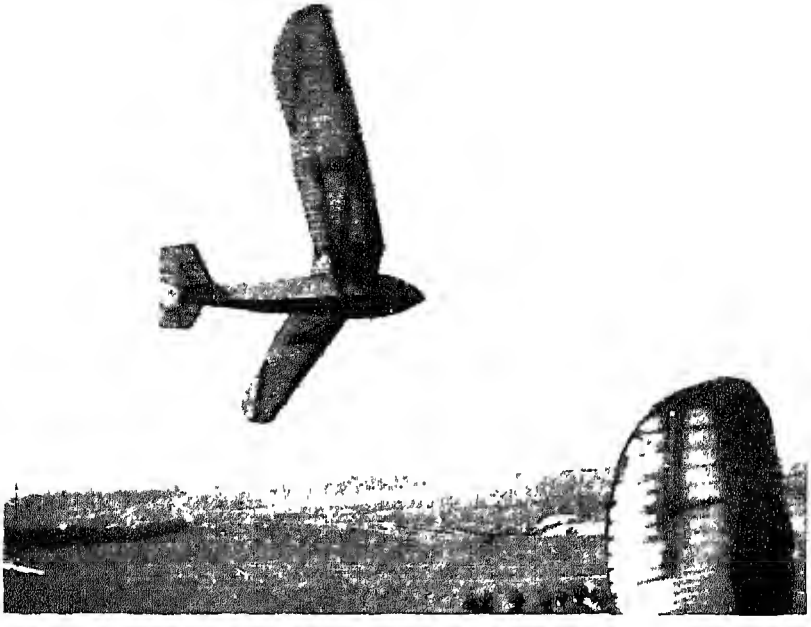


Fig. 25. *Falcon III two-seater sideslipping in to land.*

often apt to forget the strangeness, and inability to position oneself, that occurs on a first flight in a small machine.

If available, and the pupil does not object to the cost, it will be advantageous to give the first flight off an aero-tow, in calm conditions. The sailplane is in a normal attitude throughout the flight and the pupil has time to adjust himself, and relax, while height is being gained. The descent should normally consist of gentle turns interspersed with periods of straight flight. The pupil should be allowed to rest his hands and feet on the controls, and lightly follow the instructor's movements. The aero-towed flight should not last more than about twenty minutes from take-off to landing.

If an aero-tow is not available, the instructor should give the prospective pupil a couple of winch circuits, preferably without getting out of the machine in between. A first winch launch can be fairly breath-taking to someone who has never

flown at all and for this reason the instructor should take the machine up on the launch in as near a normal attitude as he can, without sacrificing too much height. The winch driver should be warned of this beforehand so that he will not have reason to think that his driving is at fault. The second winch launch may be more normal, and the pupil allowed to feel the controls on the circuit.

After landing, the instructor should always find time to have a chat with the prospective pupil to find out his reactions while they are still fresh, and to dispel any doubts and misconceptions. This is most important.

It will be normally found wise for at least a couple of hours to elapse between this flight and the actual commencement of tuition: preferably, the pupil should not start until next day, when he will have had time to absorb all his impressions.

Use and Explanation of Controls

Before the pupil starts his actual training he should be given a clear and simple explanation of the use of the controls; this can be a similar explanation to that used for solo training, with the exception of describing the actual feel of controls, which naturally varies widely between the primary trainer and the two-seater trainer.

Sequence of Air Instruction

Dual instruction in sailplanes falls naturally into two groups; that part of the instruction which can be carried out regularly, by means of simple mechanical winch circuits; and that part of the instruction which can only be carried out when the opportunity (such as thermal lift) occurs, unless the more costly aero-tow is resorted to.

A sequence of air instruction is given below in which each stage is followed as logically as possible by the next, bearing in mind the characteristics peculiar to the sailplane. Obviously it will not be possible to adhere to any fixed programme of instruction using this medium, and every opportunity of increasing the value of any flight to the pupil should be taken as it occurs.

As regards the over-enthusiastic soaring pilot who is also an instructor, he should try to remember that after any pupil

has been circled apparently interminably in a freezing thermal, he may be in no state to learn any of the things the instructor hopes to teach him on the way down.

Stage 1 — Straight Flying and Gentle Turns

As stated above, it is impossible to follow the logical system of aeroplane instruction, with practice in the use of each control separately; it must be more a case of following the instructor's example.

After the pupil has become familiar with the controls on the ground, the first training flight should be explained to him in detail.

Patter

"I will climb the machine on the winch, and when we have settled into a steady glide, I want you to put your hands and feet lightly on the controls, and follow me on a gentle left turn; we will then straighten up and fly down wind until it is time to turn across wind at the far end of the field. You will feel me go into this turn, and I want you to notice each time how much the controls seem to move. Do not look down at them but watch the changing position of the machine in relation to the horizon, especially noticing the position of the nose; when I tell you so (or waggle the stick), I want you to take your hands and feet off the controls, and notice how the machine is brought in and landed."

The circuit should be made and followed, if possible, by a second without anyone getting out of the machine, the instructor telling the pupil beforehand—

"As I level off after the winch climb, I want you to take the controls and make the turn to the left, come out, and fly straight; then turn across wind just as I did last time, if you make any errors you will feel me override you until the correct attitude or position is reached, when I will take my hands off again. Watch the position of the nose on the horizon and try to keep feeling if the speed is normal. When I waggle the stick take your hands and feet off and watch the approach as before."

This lesson should be repeated on successive circuits until the pupil is fairly proficient, or stopped altogether, before he gets stale, probably after about four circuits.

Each approach made by the instructor should be as simple and as similar to the previous one as possible, and, if the pupil seems to be taking naturally to the air, he could be allowed to keep his hands and feet lightly on the controls during the process, and also during the winch climb. The *lightness* of the grip on the controls should be stressed.

So far there have been no suggestions for patter to be made by the instructor while in the air. As each flight is so short and the explanation is given beforehand, obviously any remarks made during the flight need only be corrective, and brief, and are better left entirely to the instructor.

The first lesson should end as suggested above, and the second lesson start with a left hand circuit similar to the last flight of the previous lesson. It may be necessary to devote several subsequent lessons to the same end, with a slow pupil. On the other hand, a quick pupil may be able to go on to the next stage after only a single reminder of his previous lesson.

The next step, whether given as the second or nth lesson, should consist of a simple circuit, as before, only made to the right, ending in the pupil making successive left and right circuits, without the instructor's help in the air, but only following the instructor's approach and winch climb.

Before going on to stage two it is advisable that the pupil should have at least one longer flight (15 - 30 minutes) to consolidate what he has learnt, either by means of an aero-tow, or from thermal lift. If the pupil is backward he may need several of these flights to really get the feel of the air. In addition to straight and level flying, gentle left and right turns, and wide circles, which should be practised on this flight, the pupil should be taught straight gentle stalls and steep turns. With a quick pupil they can be demonstrated on the same flight; with a slow pupil separate flights should be given.

A suggested patter for stalls and steep turns follows.

Stalls

"When we are flying straight and level at normal speed, I want you to pull the nose up very slowly and notice both the changing attitude, and sound, of the machine, also the decreasing feel in the controls. Keep the nose absolutely straight

with the rudder so that one wing will not stall first. Continue to move the stick gently back and you will find that the nose will come up still more, and then fall away. Now there will be no feel in the controls at all until the machine has obtained more speed from its nose down or diving position. So put the stick central until the nose starts to come up to the normal position.

You will notice that the straight stall occurs at a very low speed. If you stall with rudder on, or in a turn, the speed at which control will be lost will be hgher; I want you to try this as well and watch the altimeter for the amount of height that is lost, so you will see how vital it is not to stall near the ground when coming in to land." (For spins, *see* page 70).

Steep Turns

"I want you to go into a gentle turn the same as you have made on the winch circuit, and then try to make it steeper and tighter. You will find that if you just bank more and put on extra rudder, the nose will go down and the speed increase. This is because the rudder in making the nose move towards the lower wing tip will also bring it below the horizon. You will find that by easing the stick back a little, and reducing the amount of rudder during a steep turn you will counteract the tendency for the speed to increase and at the same time keep the nose turning properly around the horizon. Remember also to keep plenty of speed in a steep turn as the load on the wings is increased when steeply banked."

When the instructor is satisfied that the pupil can fly straight with an accurate estimation of speed, and make a good turn in either direction, he should go on to Stage 2 of his instruction.

Stage 2 — Approach and Landing

Approach and landing training should first of all be made off a left-hand circuit, and practiced until this is instinctive, partly because it is easier for the pupil to learn to approach from the one direction, and partly because the left-hand circuit is standard aerodrome practice. Before completing this stage he should, however, be given practice in landing from a right-hand circuit for emergency purposes.

The actual approach technique can be divided into four groups:

(1) Plain glide landing off a left turn, for primary practice in judging speed and distances.
(2) S Turn approach for use in restricted fields, but not aerodromes.
(3) Sideslip approach.
(4) Spoiler approach.

The pupil will have been following the instructor for several approaches before he starts them himself, so should be fairly familiar with the general idea.

(1) *Plain Glide Landing Patter*

"When you are flying across wind before coming in, try to estimate when to make the turn into wind so that you will have time to make a short, absolutely straight, glide before landing. Watch your speed, and when a few feet up gently flatten out and touch down in the same way as I have been doing."

This will comprise at least one lesson, Even if the pupil is very quick he should not be permitted to go on to the next type of approach during the first lesson.

The following lessons too, should start with a similar flight to the last flight of the previous one as a reminder to the pupil.

(2) *The S turn Approach Patter*

"This time we will turn across wind for the approach higher than normal, and fly beyond the usual point for turning into wind. Then we will make a turn to the left and fly back across wind, again past the turning in point. Then a right turn across wind until we are again over our normal straight glide path, then left turn into wind, and straight glide, landing as usual." Instructor can imitate path of flight with his hand for clarity. "I want you just to follow me during the first approach and then do it yourself. If you feel at any time that you are too low to complete the three turns that I will make, turn straight in and land. Never leave your last turn into wind too late, and never, never turn away from the landing ground."

(3) *Sideslip Approach Patter*

The instructor should explain the technique of the sideslip and its part in the approach (*see* page 68).

"The sideslip is a method of losing height quickly without gain in forward speed. To make a left hand sideslip, put the stick over to the left and ease it back so that you will not pick up extra speed. As soon as the nose starts to swing round to the left, put on right (opposite) rudder to keep the nose not only from turning to the left, but to bring it to the right of the path you want the machine itself to take. On the approach we will turn into wind higher than for the plain approach, sideslip to the left and then straighten up in plenty of time to land into wind. I want you just to follow me for the first time in the usual way."

When the pupil is able to do this to the satisfaction of the instructor, he should be shown and allowed to practice sideslipping both while flying across wind, and on the actual turn into wind itself. This slipping-in turn into wind is very effective for losing height quickly in a restricted space, but the importance of landing without any slip should be stressed.

(4) *Spoiler Approach Patter*

For the spoiler approach, the instructor should first explain the use and effect of spoilers.

"When the spoilers are raised a certain amount of the lift of the wing is destroyed and the machine must glide at a steeper angle in order to keep the speed constant. This method of approach differs from the ones we have done previously in that we will land with the spoilers still in use. This will cut out the float in the final glide and so you must be prepared for the machine to touch down much more rapidly than it usually does.

First of all we will make our final turn into wind higher than for the plain approach, and then raise the spoilers. You will notice the great change in gliding angle. Remember to watch that the speed remains constant. I will make the first approach as usual, and you follow what I do."

Later the pupil can be given practice in the use of spoilers at earlier stages of the approach, and during the last turn.

He should also, if possible, be given practice in a high approach off an aero-tow or from a thermal climb. During the middle part of this longer flight he should practice turns and continuous circling.

Stage 3 — Winch Launches

The pupil will by now be very familiar with the sensation and feel of the winch launch, and should be ready to do them himself. As the instructor's flying on the launch will have been careful and good, he should explain to the pupil the errors that are possible.

Patter

"You will have felt on each winch launch that I ease the stick back quite hard as soon as we are fully airborne, and that during the climb the machine's attitude returns slowly to the more normal position. This is because, throughout the launch, the pull of the cable comes more and more from below, and the downward pull on the nose is therefore greater. If I continued to hold the nose up against this pull, the machine would start bucking fore-and-aft, with consequent strain to the structure. If you feel this starting, ease the stick forward a little until it stops. Always watch your speed on the launch, and ease the nose down a little if you are slow, and also to ease the strain if you seem to be flying much too fast."

To complete this stage (3) of his training, the pupil should be given one or two emergency landings, by the instructor releasing the winch cable when only part way up the climb.

By the time that the pupil is launching himself satisfactorily he should be making the complete circuit without the instructor's help. So as soon as the instructor is really happy about his pupil's ability, he should under suitable conditions, allow him solo.

Stage 4 — Early Solo Flying

The first solo flight can be made in one of two ways, according to the policy of the club. The pupil can either solo in the dual trainer, as in aeroplane practice, or in a comparable single-seater. If he flies the two-seater,* he will have the advantage of a familiar machine for this flight: on the other hand two-seaters

* If the two-seater is used the instructor is responsible for either fastening his harness so that it cannot foul the controls, or else removing the latter. Whichever he does, it should be done quickly, otherwise the pupil, strapped in, and watching with nothing to do, may tend to regard this operation as a man must watch his approaching execution!

are expensive. If he solos on a single-seater of like performance, he should start with two or three low straight hops to familiarise himself with the controls; this will remove much of the strangeness, and at the same time he will have the benefit of flying a type of machine eminently suited to the inexperienced soaring pilot, apart from being cheaper. The single seater is the right instrument for early soaring, as it gives the pilot a sense of responsibility, and independence—excellent qualities which are automatically developed early when the pupil is trained solo. Also, it is lighter and quicker on the controls, handier near the ground, and easier to transport if landed away from the landing ground.

Pre-solo Patter

"This time I want you to make a circuit just the same as you have been making with me on board. The only difference you will find is that without my weight the performance of the machine will be improved, so watch your approach. The machine may also float a little more just before landing, so do not try to force it on to the ground."

Once the early solo circuits are over, the pupil should be encouraged to put in as much flying time as possible, both as regards circuits, and soaring. He should be capable now of circling directly off a good winch launch.

During this time he should be watched by the instructor and any faults checked. He should complete at least five hours' flying or a minimum of fifty solo circuits at this stage, during which he should be checked at least twice on the two-seater by the instructor. These checks may usefully take the form of instruction in aero-towing, which should be definitely included at this stage.

Advanced Flying

The next stage of the pupil's tuition should be advanced dual, on a high-performance two-seater, and including instruction in blind flying. This stage should not be hurried upon the pupil, especially if he seems more interested in general flying, and taking up passengers. Advanced soaring is a sport with a particular and peculiar appeal, and it would be waste of the instructor's time to push on someone who is quite happy just pottering about, and enjoying club activities generally.

As regards taking up passengers, this can be included, at the instructor's discretion and after a suitable test, towards the end of the five hours' solo flying or its equivalent.

The advanced dual stage should start with instruction in the handling of high-performance sailplanes, and be followed by dual basic instrument flying until the instructor is satisfied that the pupil will be safe in ordinary cumulus. This should, if possible, be carried out by the original instructor, after which the pupil can be passed on to an experienced soaring pilot, who is also interested in instructing even if not very experienced in the art, for practice in cross country training and altitude flying.

Only one or two of these latter flights should be required by the keen pupil before he is quite capable of going straight away on his Silver C attempt, following a few practice circuits in a medium-high-performance single-seater.

It will be seen from this chapter that the instruction has been taken to the Silver C stage, as a standard procedure. This is the only logical step now that soaring has reached its present state of development, and one which will be expected of any club of standing.

It will also be seen that the method described is of necessity brief, as much development work has still to be done in this direction. Also there is no mention of aerobatics. These are not really necessary to the soaring pilot, but instruction can always be included in the training if the demand is there.

Chapter 4

CLUB OPERATION

BRIEFLY there are three ways in which the ordinary mortal can obtain his gliding: (1) The Clubs, which cater for all comers. (2) The Groups, which are limited both in size, and the facilities offered. (3) The Private Owners, usually not more than three or four people per machine, who depend almost entirely for ground equipment on the established clubs.

As this chapter is intended for those who wish to start to run a club this will be dealt with as fully as possible, a few remarks only being given, due to space, to the Groups, and Private Owners.

CHOICE OF SITE

Firstly, the prospective club operator must find his site. Nothing can proceed until this is done, apart from the fact that the peculiarities of the site determine to a large extent the policy of the club.

The landing ground should be big enough for all forms of general flying, and a good size to aim for is two runs of 800 yards into useful wind directions, with good approaches. This may seem at once to prohibit practically every available place, but there are extenuating factors. For instance, if the landing ground is concave and sufficiently sheltered, only one run (and its opposite) may need to be used. The ground itself need not be as smooth as is required for an aeroplane landing ground, although aeroplane take off should be safe for an experienced pilot with a glider on tow, if this form of launch is contemplated.

Provided the main landing area is large enough for safe tuition, the take off runs for winch launches, and often for aeroplanes, may be effected through suitable gaps or lanes leading from other fields.

The question of Hill Site versus Flat Field Only will force itself on the prospective club operator many times before he is finally able to decide on his site, so a few remarks on this subject may not be out of place.

One advantage of the hill is greater frequency of longer flights, especially for the inexperienced pilot, and in winter,

when thermals are not numerous. This is a great attraction, especially also to the onlooker and prospective member.

Against this may be put the fact that when the wind is blowing down the hill in any strength, the greater part of club flying may have to cease, due to lack of soaring possibilities and the existence of gusts and downcurrents dangerous for training.

On the positive side again, it is often easier to pick up and choose thermals for cross-country flights from hill lift, because of the increased chances of connection obtained from the longer flight. Against this, the pupil in his early soaring and circling stages may get into trouble through getting too low in the downcurrents behind the hill, however well he has been warned. This may prove expensive, but in any event will always be wasteful as regards the time spent in retrieving the machine.

The landing field should preferably be at the foot of the hill; although many clubs have operated, and will continue to do so successfully, from hill-top landing grounds. Not only will the club equipment be more sheltered and less liable to damage from weather at the foot, but as long as hill soaring is possible, pilots will be tempted to hang on too long in failing lift, and be forced to land at the bottom. This again is expensive in time, and so in money, if the machine cannot be flown until it has been transported back again to a landing ground on the hill top.

As regards the hill itself, this should not be less than 150-200 feet high and of smooth contour (*see* photographs of sites in chapter 9). It does not matter whether it is bare or covered in trees, both types have their good qualities, but it should preferably not be just dotted with isolated trees, pylons, or poles. These have an inevitable attraction for the inexperienced.

The absolute minimum length of the hill for ordinary soaring should not be less than half a mile, although the longer it is the better. A hill with a very short beat may soon become overcrowded in light wind conditions, and the instructor in charge will be forced to limit the number of machines in the air, which usually does not please anyone.

One last word about hills; unless the hill has very good soaring possibilities, and is really safe for training, the simple flat field should be chosen instead for the club site. One advantage of the latter is that flying can be continuously carried out in any wind direction, without danger of severe downcurrents. Also there will be more chance of obtaining a site which is

accessible to the members, if it is not necessary to have a hill as well.

A disadvantage of the flat field site is that only thermals will provide normal soaring. However, if the site is well chosen as regards its surface, and surroundings, launches consistently reach the 700-1000 feet mark, and the characteristics of the site become known, this disadvantage will be largely overcome.

For basic flying training using a winch, the flat field is better than the hill site, as the pupil is able to do circuits and turns in either direction, and will not get complexes about flying into that immovable object, the hill.

It is important when choosing the site to consider the question of population, and the transport facilities. A gliding club never has been, and may never become, a money making concern, but it would not succeed at all, if the people who wish to come cannot easily do so. The site should be as near a large centre of population as possible, and the actual flying should preferably be visible from a main road or railway station.

If there is not a sufficient supply of population to support the club adequately, the prospective operator should give up the idea, and either start a Group with limited facilities (which can always grow into a club in time), or himself join some established club. This may sound discouraging, but if a club is to run efficiently it must offer complete equipment, and only a philanthropist would be able to do this if the equipment is idle most of the time, simply because members cannot get to it without half a day's journey.

Having selected the site, the method of instruction to be used must be decided.

Choice of Instructional Method

Two methods of instruction in gliding have been dealt with in the chapter on this subject, where the suitability of each may be judged.

Here the two methods will be discussed as they affect the club operator—mostly from the financial point of view. They are, as mentioned previously, solo and dual training. Let us first examine the type of minimum layout required if the decision is to train solo.

If the club plans to train to Silver C standard, a range of

glider and sailplane types will be necessary, although this number can be appreciably reduced, if training in the first instance is to be only to the 'C' or elementary soaring stage. This need for a range of training aircraft has one advantage, it is that the earlier trainers are relatively cheap and very easy to repair, which is a benefit to the club of small income and size. It also has two disadvantages, in that a greater number and variety of spares must be carried; and, on days of gusty weather unsuitable for training, a large proportion of the aircraft will be idle, as they are useless for soaring, or flying, by experienced pilots.

It will be obvious to anyone who has anything to do with the running of a club, that each machine must do the maximum amount of work in order that it shall be as good a source of income as possible. Every gliding club has to carry quite a quantity of non-earning equipment, so any which does earn directly, must be employed to the maximum advantage. I think many people who fly club gliders would be shocked if they knew how little is earned per aircraft per year, taking the average over the club fleet.

Solo training is bad in this respect, as the majority of the flights end up far from the take off point, and time is lost in fetching them back again. Also, as mentioned previously, each machine is only useful at its own specified job, and if conditions are unsuitable, then it is idle and the income derived will be nil.

Minor breakages also must occur with greater frequency when the training is carried out solo, and these, apart from causing a further loss in income while the machine is idle under repair, also produce a positive expense.

Solo training, however, does score in one respect; in that one solo instructor can look after a larger number of pupils than can one dual instructor in a similar time; also, provided the instructor is good, he need not be a man of considerable flying experience, and will therefore probably cost less. Assistant instructors of relatively little experience can also be used to send off pupils who have reached the intermediate stages, as these instructors, being on the ground, will also be under the direct supervision of the chief instructor.

These facts, allied to the low initial cost and ease of repair of primary and secondary trainers, makes this form of tuition

suitable to the club which is starting in a small way, or without much backing.

Dual training, in which relatively few different types are required has three advantages: (1) Interchangeability of parts, and a reduction in the amount of spares which it is necessary to carry. (2) Even if conditions are hopeless for training every machine on the club is still suitable for flying, and soaring, by experienced pilots. (3) Time, and therefore money, will also be saved in the early stages of training, as the instructor will endeavour always to land the machine back near take off point. This will cut out wasted minutes between flights, and, provided members are available to fly, the earning capacity of each machine will be considerably increased. These advantages are however, offset in the beginning by the much higher initial outlay required to equip the club effectively.

There is also an indirect advantage gained by the dual, over the solo, method; prospective pupils are usually more attracted by a club equipped with sailplanes having a sleek and workmanlike appearance, than they are by machines, which although excellent trainers, have a look of the prehistoric about them.

Before going on to consider the actual amount and variety of equipment required, the prospective club operator should decide to what size he expects the club to grow within the following two years, and whether or not he intends to limit the membership. This will affect his original choice of equipment.

If he is near a very large town which has little in the way of flying and gliding facilities, he may find that he has to keep a tight hand on numbers so that the club does not grow too rapidly, get out of control, and eventually collapse. If the club is to offer good quality instruction, and flying facilities, it must keep the correct proportion of aircraft and auxiliary equipment per member. If it does not, it will become inefficient and members will start going elsewhere. If, on the other hand, enough aircraft are acquired as the membership grows to keep the proportion correct, then ground staff and equipment, and instructors, must be increased in addition, and the staff question may prove a stumbling block. Suitable people may not be available, or the increase in work may be only enough for half an instructor, so to speak: if he is not obtained, the existing instructional staff will be overworked and mistakes may be

made; if he is obtained, the extra expense may be too much of a drain on the club's resources.

As regards proportion of aircraft to members, a rough estimate when solo training is used would be about one machine to 10-15 flying members, although this would probably provide overcrowding on holidays when the weather was good. For dual training, the proportion may be slightly less, about one machine to 11-18 members.

Flight Equipment

When the site, method of instruction, and probable size of the club have been decided upon, the amount and variety of flight equipment can be selected. This equipment falls roughly into three groups. Aircraft, launching equipment, and retrieving and ancillary equipment.

The aircraft selected will, as mentioned before, be determined partly by the method of instruction decided upon, and partly upon the stage to which the training is to be taken. A club which is just starting will also have a much larger proportion of beginners to experienced pilots, and will therefore require a relatively higher proportion of trainers to sailplanes for the first year or so.

One further point, which is really a matter of preference for the chief instructor, is whether the open primary, or the secondary sailplane, is to be the first machine used by pupils when trained solo. Before the war, British clubs started with the open primary, but during the war the A.T.C. have been using the secondary as basic trainer, as is widespread practice in the U.S. The author prefers the open primary for the absolute beginner, provided that he is transferred to the secondary before any turns are attempted.* This arrangement will admittedly add one more type to the range of machines, but will be found to be cheaper in the long run, as regards repairs, and general deterioration.

If the training is to be on two-seaters, it must be decided whether the early solo flying is to be done on the dual trainer, or on a comparative single-seater.

Below are a few suggested selections of aircraft using British,

* The German S.G. 38 primary has much better controls and flying characteristics than the Dagling, and can consequently be more widely used. It is, in fact, a very good machine for early circuits.

U.S. or international types, for dual and solo training, up to elementary, and advanced, standards for clubs of 50, 100 and 200 ordinary flying members and pupils. There will not be much difference in numbers for clubs under fifty members, if it is intended to offer full facilities.

SOLO TRAINING — ELEMENTARY ONLY

50 MEMBERS	100 MEMBERS	200 MEMBERS
2 open primaries, with one detachable nacelle.	3 open primaries, with one detachable nacelle.	3 open primaries, with one detachable nacelle.
1 Cadet, with pair of Tutor wings.	2 Cadets.	1 fixed nacelle primary.
or	1 Tutor, and extra pair Tutor wings.	4 Cadets.
2 Utilities.	*or*	4 Tutors.
	5 Utilities.	*or*
1 Grunau IIb or Kite II.		10 Utilities.
	2 Grunau IIb or Kite II.	
		5 Grunau IIb or Kite II.

The Tutor wings mentioned above are not only spares, but will widen the range of machine performance as desired.

SOLO TRAINING — FULL RANGE, IN ADDITION TO ABOVE

50 MEMBERS	100 MEMBERS	200 MEMBERS
1 Gull IV or Olympia.	2 Gull IVs or Olympias.	2 Gull IVs or Olympias.
		2 Kranichs or Schweizer SGS.2.8. 2-Seaters

DUAL TRAINING — ELEMENTARY ONLY

50 MEMBERS	100 MEMBERS	200 MEMBERS
2 Dual, Slingsby, Falcon IV or Grunau 8 trainers	2 dual, as before.	4 dual, as before.
2 Solo, Grunau IIb or Kite II.	4 solo, as before.	8 solo, as before.

DUAL TRAINING — FULL RANGE, IN ADDITION TO ABOVE

50 MEMBERS	100 MEMBERS	200 MEMBERS
1 Kranich or SGS.2.8.	1 Kranich or SGS.2.8.	2 Kranichs or SGS.2.8s.
1 Gull IVs or Olympias.	2 Gull IV or Olympia.	3 Gull IVs or Olympias.

This proportion may seem on the generous side, but it is made out for a membership number which is *active*, and not merely a total on the books.

The suggested above are only examples of the class of aircraft

necessary: actual types will change as sailplanes are developed. A club may often be forced, either by cost of initial outlay, or inopportune breakage, to make do with less aircraft, and with ingenuity and hard work will probably succeed, but there is nothing so discouraging for any enthusiastic member to arrive after a difficult journey to find that there is nothing available for him to fly.

As regards spares, as large a number as possible should be carried, provided that they can be suitably stored. It will pay a small club every time to spend every penny it can afford on a good selection. For descriptions of British machines, *see* Appendix I.

Ground Equipment

Winch-launching equipment only has been included in this basic list, as it is the most widely tried form of launching in use in clubs. Auto-towing equipment would probably work out on a similar scale, but aero-towing has not been mentioned, as the cost of keeping an aeroplane solely for this job would be prohibitive in all but a heavily subsidized concern.

The amount of cable required for each winch will depend on the size of the field, and not on the number of aircraft. Signalling apparatus should also be counted per winch.

The number of winches which can be used at any one time will be determined by the size of the field. Obviously launching would be slower if the winches were so close that their cables kept getting tangled together, than if fewer winches were used and placed a good distance apart.

Also included in the tables below, which are made out on the same basis as for aircraft, are the retrieving cars, or their equivalent. If these are in first-class condition, fewer than the number listed below will be required.

Solo Training — Elementary Only

50 Members	100 Members	200 Members
2 Winches, 30-40 h.p.	2-3 Winches.	3-4 Winches.
3 Retrieving Cars.	5 Retrieving Cars.	7 Retrieving Cars.

Solo Training — Full Range, in addition to above

1 Winch, to be at least 40 h.p.

DUAL TRAINING — ELEMENTARY ONLY

50 MEMBERS	100 MEMBERS	200 MEMBERS
2 Winches.	2 Winches.	3 Winches.
2 Retrieving Cars.	3 Retrieving Cars.	5 Retrieving Cars.

DUAL TRAINING — FULL RANGE, IN ADDITION TO ABOVE

1 Winch, of 40-50 h.p.

The amount of launching and ground equipment will be less when dual training is used. This is because each flight will be longer on the average, and retrieving will be less when an instructor is doing many of the landings.

The club should plentifully supply itself with signalling flags, so that there is no excuse for the waving of invisible handkerchiefs.

A small two-wheeled trolley is a useful asset to a club, for moving gliders or heavy equipment, such as spare cable, about if a car is not available.

A number of 5-10 ft. lengths of rope, spliced into a loop at each end will be found most useful, and a spare fully charged accumulator should be always available for winches and retrieving cars.

A frequent source of delay is an inadequate, or unsupervised, refuelling system. Winches and cars seem to have a habit of running out of petrol at the very worst moment. Most club operators will have theories on this point and it will pay them well to see that their system really works.

Doubtless other ground gadgets for the smooth running of a club will suggest themselves, but these will in many cases be adapted to local conditions.

HANGARS AND CLUB BUILDINGS

Many more gliders and sailplanes can be packed into a certain size hangar than aeroplanes of a similar, or even smaller, span, because of the normal ground position of the glider; the down wing of one is able to be placed under the up wing of the one alongside, etc. Due to the resulting tendency to crowd the maximum of machines into the minimum of space it is an advantage if the hangar doors are on the side, and not at the end, of the hangar.

Glider hangars need not be high, a 7-ft. door height normally being enough, but they should be dry and well ventilated. If the inside of the roof and walls are metal, this should be painted and the paint sprinkled with sawdust while it is still wet, to prevent sweating. Protected wood, or asbestos sheet, are good materials for glider hangars.

The floor needs special attention due to the heavy wear that it will receive from having landing skids dragged over it. Wood is apt to splinter and fray, and plain concrete produces a very fine dust which in time rises in clouds whenever machines are moved, and settles in a thin film upon everything. The club operator would be well advised to consider this point carefully with the builder.

A proper workshop is a tremendous asset, and if possible should be large enough to contain a whole machine, laid out in its component parts, with room to move easily all round each item. It should contain at least one good sized work bench, and a table big enough for rib jigs or bulkheads, etc. It should be well lighted and have adequate heating, as the winter is the best time to overhaul aircraft. A small exterior dope shop big enough to hold two major components, will be found necessary: also a shed for the overhaul and storage of winches, retrieving cars, etc., although if necessary, this can be open-sided.

An area of hard standing, or concrete, outside the hangar. and extending if possible into a trailer park, will be a great asset. The immediate entrance to the hangar in winter will otherwise become quite impossible due to the continuous churning up that it will receive. A trailer park, too, in which the private owner will not be required to excavate for his trailer after a few weeks bad weather, and which is fitted with a simple anchor attachment (Diag. 4) against gales and burglars, will encourage the private owner to entrust his machine to the club, with consequent benefit to its income.

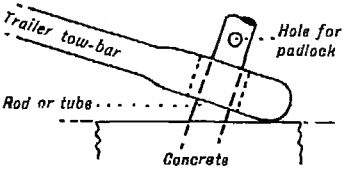


Diagram 4

If the club intends to go in for the catering and residential side, it is essential that this should be done properly, although this does not mean that it need be either luxurious or expensive. this does not mean that it need be either luxurious or expensive (Fig. 27).

All buildings should be laid out with a view to future expansion, and the club house should be constructed so that it can be added to without difficulty: it should possess a good view of the flying, and landing ground (Fig. 26).

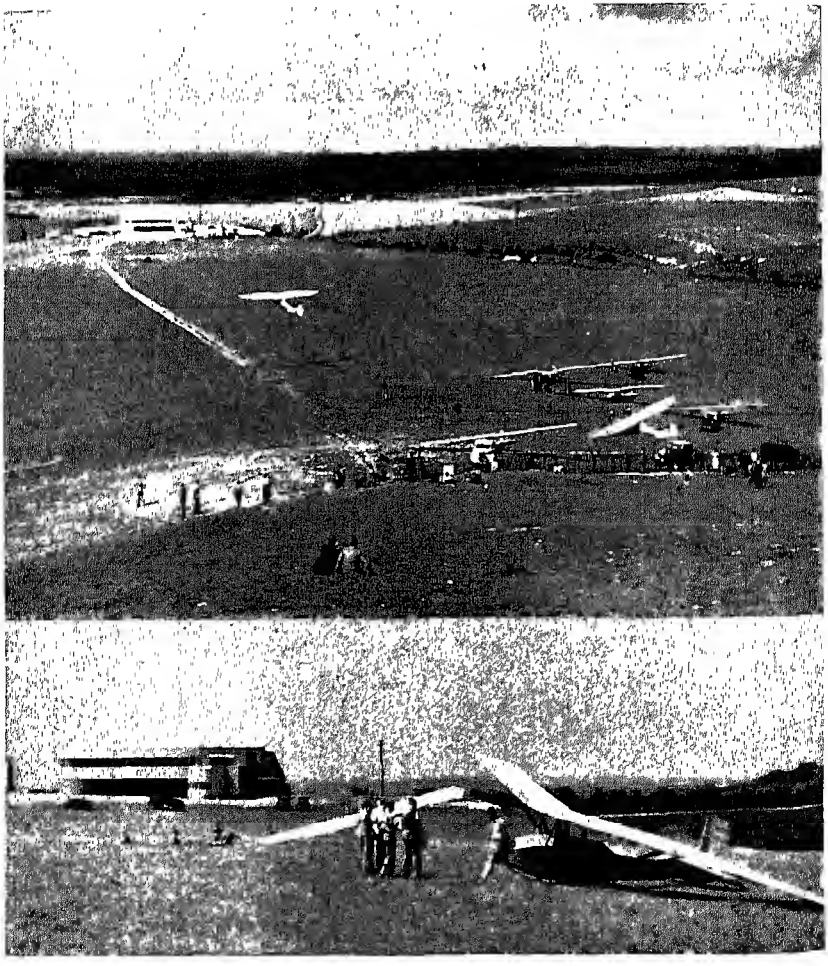


Fig. 26. *Club house, hangar and main landing ground of the London Gliding Club.*

Quite a suitable layout for a first club house could be on the lines suggested below. A verandahed main room big enough for small dances, club dinners, table tennis and film shows, with a bar-cum-snack-counter room to one end with a cloak-room off a passage behind (this passage being ready for an extension for dining-room, etc., on to the end of the building). At the other end there could be two small offices, which can be added to quite easily, and at the back a bunk house, or bedrooms, as seems desired.

This building may be built of wood, and a builder will be probably able to use existing sections for a great deal of it. A large open brick fireplace in the central room will be a pleasant and effective addition, and give the structure an air of permanence.

With regard to other buildings, a small and simple shelter at some point where flying is frequently carried out, but at a distance from the club buildings, will add to the comfort of members and instructors in the less pleasant weather.

Staff

In the past, British gliding clubs have operated largely with a voluntary staff and management, adding a skilled general factotum as the opportunity occurred. The usual jobs done by this man-about-the-house were numerous and often included repairer, steward, clerk, and assistant instructor; the post of chief instructor being a voluntary one. The good reputation of the main clubs at the outbreak of war showing how well this job was carried out.

The second step in the acquisition of paid staff was often a Chief Instructor-manager. This addition became necessary as soon as the club had enough active members to open on week-days, when it was not possible for the voluntary instructors to give their time. This policy produced an adequate return.

Gliding seems to produce people who can turn their hand to more than one job successfully, and this is very fortunate where club staff is concerned, as income is seldom able to justify a full complement of paid men.

The ideal would seem to be a nucleus of professional staff, backed up by suitably qualified members who are keen enough to give their time voluntarily.

Some clubs operate on a rota system as regards their voluntary help, but unless this is absolutely necessary, it should be avoided, as being tied to certain dates and times is often apt to take a great deal of pleasure from the services rendered. An exception to this will naturally occur on bank holidays and on special courses, when it is essential to know that a sufficient number of helpers will be available.

Some of the routine work of an active gliding club follows, and may be done by a combination of paid staff doing one or more jobs each, and voluntary help. The final proportions being suited to the local conditions and personnel available.

(1) Flight Instruction: one full-time paid man will enormously increase the club's facilities.

In a newly-formed club assistant instructors from among the members can be available sooner if the training is carried out solo, than if it is dual. A dual instructor must be absolutely capable of instructing without supervision, whereas a solo instructor, probably driving a second winch for simple circuits, can be watched over by the chief instructor, and any criticisms made at once.

(2) Winch driving (other than for solo instructional purposes): voluntary, members can take turns with ordinary launching.

(3) Motor Transport Maintenance: probably voluntary, unless done as a combined job with something else; or under contract with a local garage.

(4) Aircraft Maintenance and Repair: preferably professional and full-time. This is work which must not be skimped or hurried. It can either be done by a capable, but unqualified, workman under the supervision of a qualified man who inspects as required; or preferably by a man qualified to inspect his own work. Alternatively, all but minor repairs can be contracted to a local firm, and the odd temporary and minor repairs done by some other capable member of the staff.

(5) Administration (including manager, secretary, clerk, and collector of money). Preferably paid, but quite possible voluntary, if the member in question can keep up his enthusiasm for a very arduous job. If possible, this work should not be attempted by a flight instructor, or even the aircraft maintenance man, as it would be an exceptional person who could do both without one job or the other suffering. In a growing and efficient club, the keeping of records, and the correspondence,

are as necessary to its smooth running as instructing and maintenance, even though less interesting.

(6) General Staff and Catering: the staff required here depends very much on the extent to which the club offers meals, beds, and recreation facilities. Obviously it would be wasteful to keep a man just to lock up and sweep out the hangar and club-house.

An arrangement for residential facilities and meals with a nearby pub. can often be most useful to a club in its early stages, but when the club decides to have its own bar, meals or snacks, and bedrooms or bunkhouse, it needs someone to keep the whole place in order, the bedding aired, and the equipment clean. This is a job which cannot usually be done well voluntarily, although this might be managed if the place is only open for weekends.

From the above, it would appear that the minimum number of paid staff to look after a club offering full facilities, might be four, as follows:

(1) An instructor, whose job is not only to train pupils, but also to train and supervise his assistants, and generally watch over all the flying and landing ground operations, and to consistently work at improving the methods in use.

(2) A manager-secretary, to look after all the administrative work, such as:

Collection of forms, certificates, photographs, and fees from members for the application or renewal of licences or gliding certificates.

Collection and entering of subscriptions, fees, and other income derived.

Supervision of certificates of airworthiness, insurance, and any form of dues, capitation fees, or other payment to Central Organisation, if any.

Payment of wages and accounts.

Writing of agenda or minutes for management, or club committee meetings.

Arrangement of camps, courses, lectures, etc.

Responsibility for seeing that log books are kept up to date, club notes are sent in to relevant journal on time, and that advertising, if any, is up-to-date and adequate.

It is a good and democratic tip, if a member has a particular

grouse, to whip him on to the sub-committee dealing with the matter, so that he can either put it right or see the difficulties inherent in his suggestion.

(3) A ground engineer, to repair and maintain all aircraft and spares, inform the secretary about certificates of air-worthiness, and other returns, when due. Repair private-owner's aircraft to bring in extra income, and spend spare time, if any, working on developments or adaptation of aircraft to local conditions. Also to keep an eye on ground equipment, if this is being maintained voluntarily or under outside contract.

(4) Club-house staff-cum-steward, to look after the club-house and equipment, etc.; to order food and drink, and keep accounts, either alone or in conjunction with the secretary. To prepare suitable meals or snacks when required, and generally make and keep the place as attractive as possible, even to the extent of a little gardening. If a club house is to be provided at all, it must be pleasant and efficiently run. In this way it will help to pay for itself, by attracting members' families, as well as a number of non-flying members, who just want some pleasant place to spend their week-ends and watch the flying.

The above is only a suggested arrangement, as so much depends upon local conditions.

Insurance

Every club glider and sailplane must hold a Third Party Insurance Certificate, minimum £2000. This is not expensive, and even if it were not compulsory, any club would be foolish in the extreme not to be covered. Beyond this point, different clubs have different ideas about insurance.

Some clubs pay third party only, and pay for all repairs themselves with the exception of the first £3 - £10 per breakage, according to machine type, which is paid by the member concerned. With this method the club depends a great deal on luck. One year practically all repairs may be covered by the members' liability, in other years the club may end up badly off indeed.

Another method, better suited to the medium-sized club of average means, is to insure comprehensive excluding the first £25, charging members the first £3 - £5 as before. This form of insurance will be more expensive, but will definitely pay if the club is unlucky enough to get more than two major

breakages on trainer machines, or one on high-performance sailplanes, in any year.

It is possible, of course, to insure all club aircraft Fully Comprehensive, but the cost of this is normally prohibitive, and certainly not worth the money in any reliable club.

Some clubs run, in addition, an internal insurance scheme of their own, to cover members for the £3 - £5 liability.

This is not compulsory, but usually takes the form of an additional fixed sum per annum, such as £1 1s., which covers the member against any liability for that year. It will pay a club to do this if enough members will join in, but not otherwise.

Committees

A club committee, composed of club members, who are elected annually by the members themselves, adds to the smooth running of a club, as all members are able to feel that they are part of the organisation, and any grumbles or suggestions will come to the management before they cause any trouble.

The usual committee is representative of the various forms of club activity and normally includes full flying members, both experienced and under training (although the latter are frequently only co-opted when required, as it is often difficult to obtain a suitable committeeman from among new members). Private owner members. Members who have interested themselves in the upkeep of ground equipment, or as assistant instructors, or with the catering, etc., and any others who have the club's welfare at heart. The secretary, and manager, etc. The usual difficulty is to keep the committee small enough so that it is not unwieldy, and can work quickly and smoothly. A large club committee is usually a useless affair.

Income

Unless there is any form of government subsidy, the main sources of income in a gliding club comes from subscriptions, although due to the nature of glider flying and its low training charges, a subsidy of some form is at present necessary, unless the cost to members is to rise to an extent whereby the keen member of ordinary means will be prohibited from carrying on his training to a stage, useful either to himself, or anyone

else. The usual entrance fee and subscription to any of the main British Gliding Clubs in 1939 averaged a £1 1s. entrance and £2 2s. - £3 3s. per annum for full flying membership. These, however, have unfortunately doubled themselves under immediate post-war conditions, due to the very considerably increased cost of club equipment.

Private owners usually paid the entrance fee and £1 1s. - £2 2s. per annum, and non-flying members paid the entrance fee and about £1 1s. per annum.

The next source of income is that derived from flying fees. Before the war, solo training in this country cost about 3/- per day on primaries, soaring 6/- per hour, and circuits or launches 1/6 a time, on medium-performance aircraft High-performance aircraft were more expensive.

These charges, too, have increased to about double. As regards dual training, the costs here will be higher, but the training should be quicker, which would compensate for the higher cost. Dual instruction at present costs about 15s. - £1 per hour, and circuits about 3/6. Solo flying on medium performance single-seaters may cost about 10s. - 15s. per hour, and 2/6 per circuit. Launches for private owners will also cost about 2/6. These figures are based on the estimated cost of a club of about 200 members operated without subsidy, but not making any profit. Obviously a smaller club would find it difficult to cover itself, charging the above rates.

Catering is another source of income, and it is essential that this should pay for itself, and make a profit. The flying side will probably never be able to support the club and catering side, so it would be better to offer no facilities in this respect, unless they can at least pay for themselves.

Camps and courses will not be counted here as sources of extra income, as they are really only temporary increases in ordinary club flying, and the income and outlay involved should be dealt with as such.

Income may also be derived from passenger trips to outsiders, although a careful watch should be kept that neither insurance, or any licence, is invalidated by doing this. It is usual procedure to make the prospective passenger a temporary club member, and obtain a signature indemnifying the club in case of accident, before taking him up.

Another form of outside income may come from providing

a public enclosure with a good view of the flying, and if possible a simple shelter, and selling such things as booklets on gliding, or ice cream, either directly or under contract.

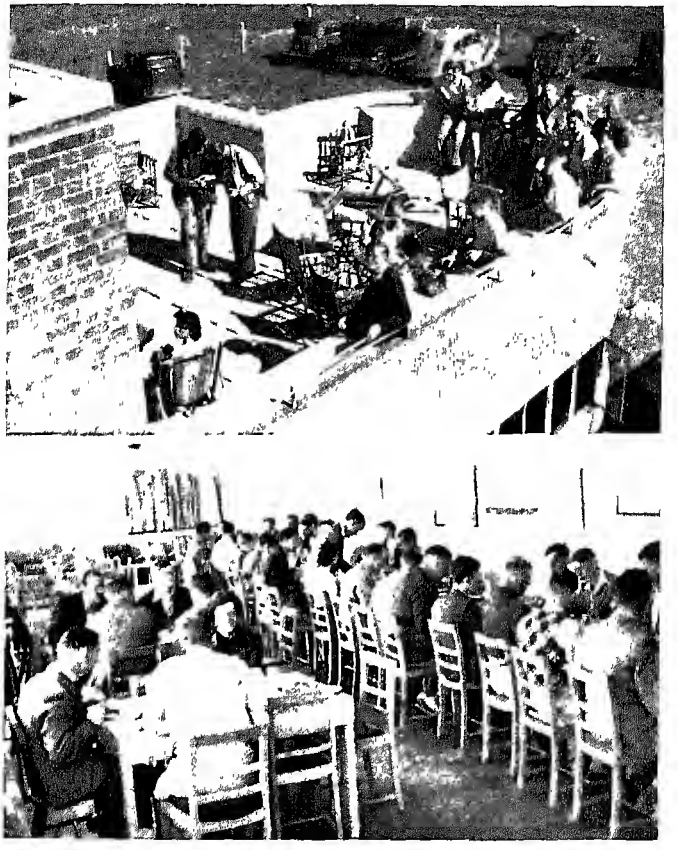


Fig. 27 (*Top*) *the balcony above the bar at Dunstable.* (*Bottom*) *the dining-room.*

These last mentioned forms of income are important, and should be exploited to the ultimate benefit of the club members, although perhaps at the risk of losing a few of the more purist members meanwhile. Other income may come from trailer

parking of private owner's machines, sale of log books, club and car badges, association journals and other books, model sailplanes, and photographs or paintings of gliding, and sundry other items.

Apart from capital costs (hangars, aircraft, etc.) and wages, one of the highest running costs of a gliding club is insurance, followed by capitation or association fees, and Certificate of Airworthiness fees.

It will not be of much use to put in a sample balance sheet of capital, running costs, and income here, as costs at present are so very fluid; it is enough to say that anyone attempting to start a gliding club will be well rewarded by going into this question most carefully and extensively, as an ordinary unsubsidised gliding club offers such slender returns that the maximum ingenuity and forethought must be devoted to its operation, together with every consideration for the local conditions.

Groups

If the prospective club operator decides that the local population is not sufficient to support a club, but there exist about a dozen enthusiasts within reach who would like to get some gliding, he can form a group, which offers very limited facilities, and which does not intend, for the present, to expand. This will cost its members more than the ordinary club (although with certain advantages, such as greater freedom of movement and more frequent chances of flying).

It is essential that at least one member of the group should be capable of launching, and flying, safely, and it should be agreed that with regard to any flying question or disagreement, he will have the last word. Another point necessary to the smooth running of the group is that all the other members should start equal, if possible, as regards their standard of training, or flying. It will pay them to try to achieve this through joining one, or more, of the many residential training courses offered by nearly all the bigger clubs, before the group commences its activities.

It is rarely satisfactory to start a group with members who have never flown anything before, as they will all progress at different rates, and the ones who get left behind will get dis-

couraged because they don't get on, and the more advanced ones will get discouraged because they are being held back, and this usually means the early termination of the group.

The ideal stage for the group to start is when all the members have reached the secondary stage, and have done sufficient elementary soaring to obtain their 'C' certificate, or 'A' licence, and it will pay the organiser to insist that any prospective members reach this stage before joining.

With regard to the site, aircraft, and ground equipment. The choice of site for a group will be much wider than for a club, as it is not necessary to put up hangars or any permanent fixtures, and any rent paid will probably be small. Land on the top of a hill, good for soaring in frequent wind directions, is more suitable for a group than a club, as launches can be made by bungy, hand or car stretched, without the need for a special winch. This will cut down the cost per member quite considerably. The increased mobility of a group also allows it to go to an established club, even if the distance is considerable, on days when their own hill is useless for soaring.

Another quite suitable site for a group is a long stretch of sandy beach. Cliffs are often good for hill soaring, although not much use for thermals. The beach may provide a great enough length for auto-towing which probably can be done by the members' cars, again saving the cost of a special winch.

With the operation of a group, it is important to cut down costs wherever possible, and without any doubt bungy launching is the cheapest form of launch, with auto-towing second, and winch launching third, although for an established club where each piece of equipment can and must do sufficient work per year to pay for itself, the winch is probably the most suitable.

With aircraft too, the machine which is excellent for a Club, may not be the best for a Group. It was stated above that if possible all group members should be safe when flying a secondary sailplane. One reason for this is that if the first machine a group possesses is too elementary for even early soaring practice, it will soon need to be changed for a more advanced one, with consequently increased cost per member. A machine should be chosen which can be used for the longest time before it is "outgrown", even if this means a slightly

higher first cost. Three machines, at present in existence, come to mind as suitable for this class of flying.

(1) The American Utility, which has a slightly higher wing loading and landing speed than most European types; it has a reasonable soaring performance when fitted with a transparent hood.

(2) The German Falke (or British Falcon). This is a stable and safe machine with a very good light wind soaring performance, its only drawback, however, is that extensive experience on it may inculcate sloppy flying habits. It is, however, not being manufactured at present.

(3) By far the best machine for the secondary Group is the British Cadet, which may be changed to the secondary-intermediate Tutor by merely fitting a different pair of wings, and which can take on the character of an intermediate by the fitting of a detachable transparent cockpit cover. This machine, even with the additional spare Tutor wings, compares in price with either of the first two mentioned, and provides for the range of capabilities and experiences, which soon becomes apparent in any group of pilots.

When all the active pilots in the Group have reached a standard of efficiency which warrants the use of a more advanced machine, this can either be added to the group, and the group expanded by suitable new secondary stage applicants, to cover part of the cost, or the previous machine can be sold in part exchange. It would be as well to make provisional arrangements to this effect with the makers when acquiring the first machine.

In the above manner, the group can finally grow into a full club, or it can remain the same size as it began, but finally develop to a very high state of efficiency and pilotage.

When the group is first formed endless trouble will be saved if a written agreement covering all possible conditions, costs, and exigencies is made out, and signed by each member, especially as regards responsibility of payment for breakages, and insurance, etc. Flying fees should be charged, as this will enable a reserve to be built up against depreciation, damage, and the purchasing of spares.

It is not easy to give approximate costs for a Group under present conditions, and anyway a great deal will depend on the rent of the site, and the method of launching which has to be employed. Approximately the best number of members in a

one-machine Group is 10-15, as this should always provide sufficient people to enable flying to be carried out easily, and at the same time keep the cost per member within reasonable limits. When the group reaches the more advanced stages, and if it still possesses only one machine, each member will get more chance of flying if the group only consists of 7-10 members, although this will increase the cost per head.

Private Ownership

Private Ownership differs from the Group in that the machine will be owned by only one, to a maximum of five pilots, who will probably have considerable experience, or be passed all but the advanced training stage. They will rely to a large extent on the facilities of the established Club for their ground equipment (Fig. 28).

Although it is always possible for a Group to attach itself to an established club, its strength is in its independence. The

Fig. 28. *Private owners' sailplanes and trailers visit the Surrey Gliding Club.*

private owner, to obtain any real use from his machine, should at the most be within an hour-and-a-half's journey of his usual club.

As regards cost, the Private Owner will find his sail-flying costs him more, in initial outlay, if not in running expenses, than the group unless the latter is unfortunate in its rent, etc. On the other hand, private ownership allows of considerably more flying time per member than it is possible in a Group or Club.

The internal workings of any Private Owner partnership can only be decided between the members, as all are normally of equal standard, and are usually well known to each other before buying their machine, whereas a Group often starts with a number of semi-strangers in its ranks, and requires that one of its number be in charge of proceedings until each member has sufficient experience to act reliably on his own.

The main advantage of Private Ownership is the great freedom it affords; open meetings, national competitions, visits to other clubs and sites can all be enjoyed with the minimum of arrangement and discussion.

Chapter 5

METEOROLOGY

THE term "advanced soaring" covers any kind of soaring that demands more skill than that needed for merely staying up over a single hill or ridge. The skill consists in combining a knowledge of the performance of a sailplane with an understanding of the behaviour of the atmosphere—that is, of meteorology.

An advanced soaring pilot has no need to master the entire contents of a standard meteorological text-book; in fact, a large part of the knowledge he needs is not to be found in such a book at all, and has had to be discovered by his predecessors for themselves. But in order to absorb this information one must at least understand the language in which it is given out. In other words, one must learn some elementary meteorology before being told how to apply it.

What needs to be learnt can be grouped under the headings of wind, temperature, clouds and weather.

WIND

In scientific terms a horizontal motion of the air is called a *wind*, while a vertical motion, either up or down, is called a *current*. Air moving obliquely upwards is therefore both a wind and a current; that part of it which is a wind is then called the *horizontal component*, and the current the *vertical component*. If, for instance, a slanting air stream blows up a slope of 1 in 5, the horizontal component is five times the vertical component, so there is five times as much wind as current. But whether a sailplane can soar in it depends entirely on the strength of the vertical component or current; all that the horizontal component, or wind, can do is merely to modify the sailplane's course in relation to the ground.

Upward-moving air should be called an *up-current*. In some languages it is called an up-wind, but in English "up-wind" means contrary to the wind direction, while "down-wind" denotes with the wind. So, for the same reason, downward-moving air should be called a *down-current*.

Friction

Friction against the ground has a marked effect in slowing up the wind at low levels. It is slowed up more by rough ground than by smooth, and more over land than over sea.

Only at heights of 2,000 feet or more is the wind speed unaffected by ground friction; its value can then be calculated from known differences of barometric pressure, called the *barometric gradient*, which give rise to it; and therefore the wind at this height is called the *gradient wind*. Below the height of the gradient wind, the slowing-up becomes gradually more noticeable as the ground is approached, and the particles of air in actual contact with the ground, like those in contact with the surface of an aerofoil, are at rest.

The wind speeds reported by meteorological stations are measured at a standard height of 33 feet (10 metres) above the ground; at this height it is found to blow, on the average, only one-third as fast as the gradient wind, or over the sea two-thirds as fast.

The most marked effect is found close to the ground. For instance, at a height of 20 inches the average wind speed is only about half that at 33 feet, and at 5 feet (the average height of the human face) it is some two-thirds of that at 33 feet, or about a quarter of the gradient wind.

The rate at which the wind increases with increasing height is called the *velocity gradient*. (The word *gradient*, originally used to indicate steepness of a slope, can be used to express the *rate* of a change with position of any physical quantity; so also the word *steep* denotes a large gradient of any kind).

The velocity gradient is at its steepest near the ground. For instance, in the first 20 inches the wind speed may increase from *nil* to about a sixth of the gradient wind; but one must go up more than 30 feet higher to find a further increase of the same amount.

A glider or sailplane is affected by the velocity gradient in two ways.

If, after a launch into still air, it is made to climb upwards, it will rapidly lose speed because of the backward pull of gravity. But if it climbs against a strong wind, though it still loses speed relative to the ground, it loses much less, or none at all, relative to the air, because of the increased wind blowing against it at the height to which it has risen. It is by this means that the

albatross can soar dynamically from sea level up to 40 or 50 feet against a wind blowing half a gale. But the velocity gradient is much steeper close to the sea than it is close above land, and a glider cannot usually be expected to perform the same feat unless it is launched from ground level with some extra speed in hand.

It is well to remember that, on descending to earth against the wind, the opposite effect will come into play; a glider or sailplane must descend more steeply than its normal gliding angle or it will eventually stall as it comes into slower-moving air. Theoretically, the glide should be made steeper the closer the earth is approached, but this would involve diving into the ground; in practice, of course, the pilot must flatten out to land, so before doing so he should steepen the glide still more to gather excess speed.

The other effect of the velocity gradient makes itself felt when a glider becomes steeply banked when flying sideways to the wind. The higher wing is then in a faster air stream than the lower. To take an example from statistics given by Dines: a gradient wind of about 40 m.p.h. was found, under average conditions, to blow at 20 m.p.h. at 300 feet and 16 m.p.h. at 150 feet. Calculation shows that between these two heights a vertically banked sailplane would tend to roll at a little over 2 degrees per second. Nearer the ground, where primary gliders operate, the effect is much more pronounced.

The steepest velocity gradients above open ground are concentrated in the lowest foot or two, but over rough ground or vegetation the steeper gradients are distributed through a greater height, especially above trees. So a sailplane making turns just over a wooded slope is in a steeper velocity gradient than it would be over open ground. More than one sailplane has fallen among trees after an excessively banked turn in such a situation, owing to the greater overturning effect.

Turbulence

Friction of moving air against the ground sets up turbulent eddies. These are felt by an aircraft as sudden changes of wind speed or direction. The fluctuations are equally evident in all three dimensions, except very near the ground where the vertical ones are slightly reduced. To anyone standing on the ground, lateral movements appear as alterations in wind direction, while

fluctuations parallel to the wind cause gusts and lulls, resulting in a variation of wind speed usually between 50 per cent above, and 50 per cent below, its average velocity.

A pilot flying in a turbulent 20-mile-an-hour wind must therefore be prepared for a sudden increase or decrease of flying speed of up to 10 miles an hour. Because of this he may easily be left in a stalled condition at the onset of a lull. But fortunately these eddies are of small dimensions; though they vary individually, a typical eddy in such a wind might be 150 feet across and therefore last about 5 seconds, while many are smaller than this. So in normal conditions a pilot need not go into a violent dive to pick up speed when caught in a lull; he can wait a few seconds for the wind to recover and unstall him.

A sudden gust, on the other hand, may often be usefully employed to gain height during its onset. A sailplane flying down-wind can likewise gain height dynamically as it overtakes the front edge of the gust.

In theory, the correct way to use gust energy is to fly across the wind direction during the onset of a lull, and parallel to it (either up-wind or down-wind) at the onset of a gust; but unfortunately the gusts and lulls are invisible. Furthermore, it is only when facing the wind over a slope that an occasional few feet of extra height are so valuable.

So the commonest way of using gust energy in practice is to face the wind all the time and raise the nose at every sudden increase of air speed. It can be shown that the height gained in this way is more than that lost in the subsequent lull, even if the sailplane continues to face the wind.

Gusts tend to break into slower-moving air with a downward trend, especially at low levels. This is because of the velocity gradient; in turbulent winds, any downward-moving air brings with it some of the momentum of the faster wind stream above. For a similar reason, upward-moving air tends to slow down the layer into which it rises. It is obvious that this phenomenon tends to reduce the lifting effect of gusts on a sailplane, but in practice any downward trend of gusts or upward trend of lulls has not been noticed.

Deflection

Uneven ground alters the wind flow over it. For instance, every soaring pilot looks for an up-current over the windward face

of a hill, and expects a down-current somewhere to leeward of the hilltop.

The vertical component of a wind blowing up a slope is called *slope lift* (or sometimes "hill lift"). If the speed of this up-current is equal to the sinking rate of a sailplane using it, then the machine will just maintain height. If it is more, the sailplane climbs; if it is less, the sailplane sinks, though not so fast as it would in the absence of slope lift.

When wind is deflected up a slope which is not excessively steep, the angle of upward deflection is greatest close to the slope, where the air stream follows the contour of the ground. But this air is much slowed up by friction; so the strongest slope lift is not found there, but higher up where the air stream, though not ascending so steeply, is blowing very much faster, thus giving a larger vertical component. As we go higher still, the angle of upward deflection becomes less and less, and, in spite of some further increase of the wind strength, the vertical component is reduced until it can no longer support a sailplane. In a strong wind the height *above the hilltop* at which this happens is, on the average, three times the height of the hill where an extended ridge lies transverse to the wind, but only one-third of the height of the hill in the case of an isolated hill.

Where a slope varies in steepness from bottom to top, a good rule is to look for the best lift vertically above the steepest part of the slope. However, the rule does not apply to a very steep slope, which dams up the air in front of it, so that then the best lift must be sought well up-wind where the wind flow is deflected upwards by the dammed-up air rather than by the solid face of the hill.

A related phenomenon is found where the wind blows in from sea to land, or from open, flat ground to woods or other irregularities; it is then slowed up by friction, and the slowed-up air acts in the manner of a solid hill and deflects the oncoming wind upwards over it. Soaring in this type of lift was done at Cranz in 1927, but there is no record of its having been performed since.

On the lee side of a hill the air stream does not follow the contours down unless they are very gentle. Instead, it usually ignores the lee slope and travels on, only gradually descending to earth, and leaving below it a zone of dead air, or of eddies,

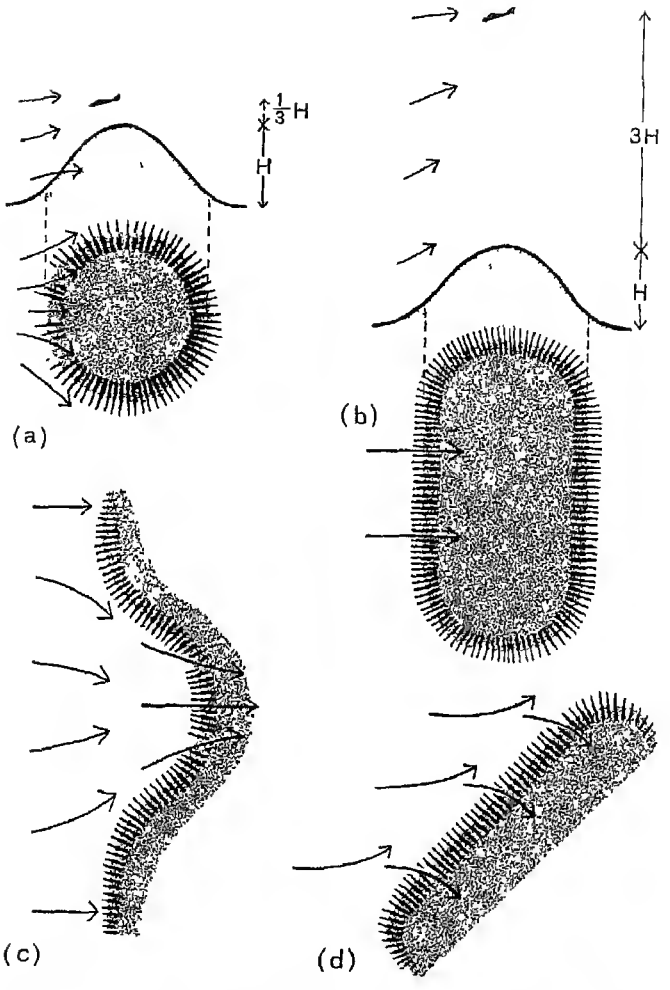


Diagram 5. *Influence of the shape of a hill on the strength of slope lift.*

(a) Vertical section and plan of an isolated hill, showing the wind-flow. The slope lift extends to only about one-third the height of the hill above its top, as much of the wind-flow is diverted round the side of the hill.

(b) An extended ridge lying transverse to the wind direction. The wind blows directly up the hill, and slope lift extends to about three times the height of the hill.

(c) Wind blowing into a cup or horseshoe-shaped ridge is compressed laterally and its speed is increased, giving stronger slope lift.

(d) Wind blowing obliquely against a ridge is diverted partly parallel to the ridge and partly in the opposite direction over the top.

in contact with the lee slope. Yachtsmen reckon this region of dead air in the lee of an obstacle (such as a hill, cliff or belt of trees) to extend down-wind to a distance of four times the height of the obstacle. But the distance at which the descending air stream again becomes horizontal can be roughly estimated by Georgii's formula: multiply the height of the hill or mountain (from base to summit) by the cotangent of half the angle of its windward slope. Some examples are given in the accompanying diagrams.

There is liable to be a sharp boundary between the descending air stream and the dead air below it, giving a very steep velocity gradient at that point. So a sailplane approaching to land in the lee of an obstacle should do so at a *ground* speed greater than the (air) speed at which it stalls.

The zone of comparatively quiet air in the lee of a hill is called a *wind shadow*.

So much for vertical deflections. But it is important to remember that the wind flow over uneven ground can be altered in all three dimensions, as it is by turbulence.

For instance, wind deviates laterally to flow round the side of a hill. It will also deviate laterally when it strikes a ridge lying obliquely to the wind direction; the deviation is greater the steeper the face of the ridge, and is especially marked where the ridge forms one side of a valley. But to compensate for this there is an opposite deviation just over the crest, where the wind tends to cross it at right angles to the line of the ridge. That is to say, some of the air still goes up the slope and crosses the top.

With a wind direction as oblique as 30 degrees from the line of a ridge there is, according to investigations by C. E. Hardwick at the Long Mynd, only a narrow belt of lift directly above the upper half of the slope, with a down-current above the crest and a milder down-current above the lower half of the slope.

The third dimension in which wind can deviate is fore-and-aft, which is the same thing as an alteration in wind speed. A reduction of speed to leeward of an obstacle has already been mentioned.

An increase of speed, on the other hand, is caused by a wind stream becoming compressed. For instance, wind blowing into a horseshoe-shaped ridge is compressed laterally, and blows up and over the inside of the horseshoe at a much greater speed than it would over a straight ridge. Thus both the horizontal and

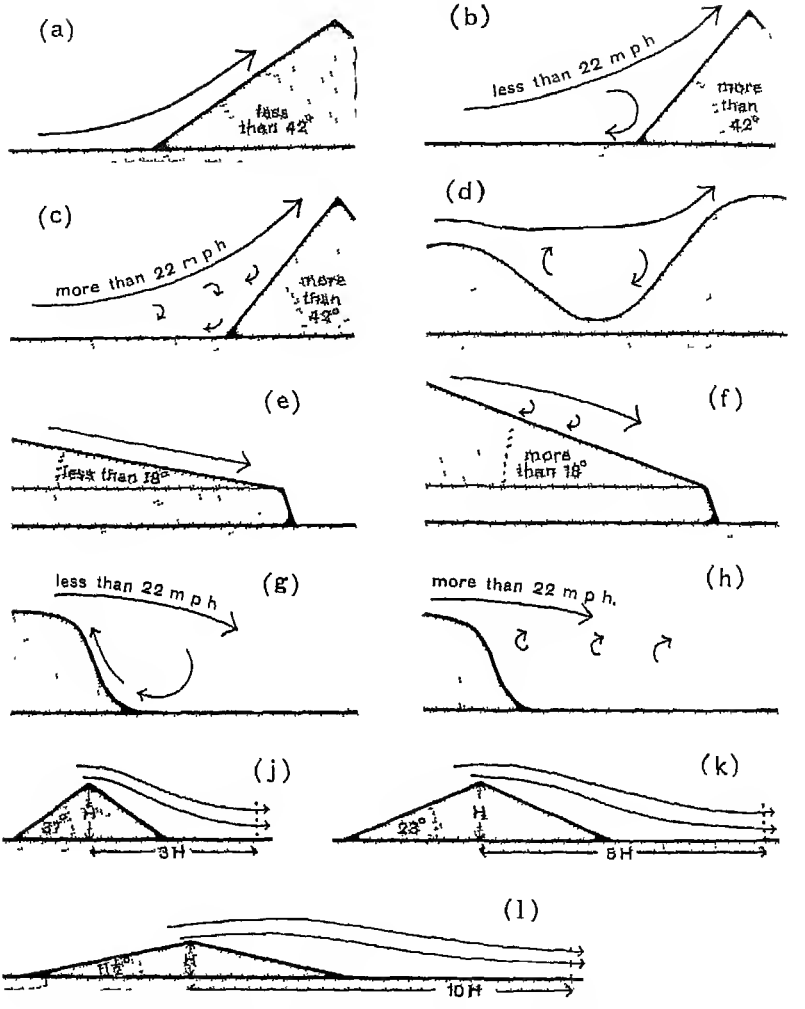


Diagram 6 *Flow of air over windward and leeward slopes*

These diagrams show the results of experiments by W. Welzenboch on artificial snow slopes, combined with observations by W. Georgii in mountainous country. The figures given must be taken as only a rough guide, as the diagrams show idealized slopes, whereas natural slopes are irregular and of varying degrees of roughness

(a), (b) and (c) show how the windward flow depends on angle of slope and wind speed

(d) shows the effect of "blanketing" of a slope by another hill a short distance up-wind

(e), (f), (g) and (h) show similar effects over a leeward slope

(j), (k) and (l) show examples of the application of a formula given by Georgii, who states that the distance to which a mountain influences the air-flow down-wind is equal to the height of the windward slope above its base, multiplied by the cotangent of half its angle of slope ($R = H \cot \alpha/2$).

vertical components are increased; slope lift is stronger there, but a pilot using it must allow for the increased wind speed too, or he may drift backwards out of the lift. Some of the air blowing into a "horseshoe," a bowl, or a narrowing valley, escapes upwards from being laterally compressed, producing an up-current well in front of the real slope lift.

Wind blowing up a slope tends to be compressed vertically because of the inertia of the air higher up; here again an increase in speed results. But the magnitude of this effect is much modified by temperature differences. It may disappear altogether over heated ground, while air cooled by contact with cold ground may refuse to flow uphill at all. The reasons for this will be given in the next section.

Decrease in wind velocity may be expected at the bottom of a steep windward slope, or close to a leeward slope, unless it is a gentle one. In these situations a large eddy may form and cause an actual reversal of the wind flow, unless the wind is so strong as to churn the air into smaller eddies by turbulence.

With a wind blowing *across* a steep-sided narrow valley, the windward and leeward reversals may join up, the connecting link being a reversed wind flow across the floor of the valley, blowing in the opposite direction to the general wind stream above.

All these deviations of wind flow will be better appreciated by referring to diagrams 5 and 6.

Temperature

Consider a bath full of water. If it has been left undisturbed for a time, the water will probably be found colder at the bottom than at the surface. Since the cold water is denser than the warmer water above it, it is heavier, and therefore stays on the bottom. A layer of fluid (such as water *or* air) in this state, in which that at the bottom tends to stay below and that at the top to stay on top, it is said to be *stable*, or in a condition of *stability*, because such a condition tends to persist.

If now the bottom of the bath is heated, say by a number of gas jets placed underneath, then the water at the bottom becomes hotter and lighter than the water just above it, and tends to rise. A layer of fluid in which that at the bottom tends to rise to the top, and that at the top to fall to the bottom, is said to be

unstable, or in a condition of *instability*, because such a condition cannot last if left to itself, once the slightest initial disturbance has set it overturning.

An unstable condition tends to be brought to an end by the starting up of vertical currents, the hotter water rising and the cooler descending, until all the water in the layer is thoroughly mixed and brought to the same temperature. The process is called *convection*; the currents are called *convection currents*; and the disturbance set up by them is called *convectional turbulence*.

A well-mixed layer of water, at the same temperature throughout, is neither stable nor unstable. But it is nevertheless bordering on instability, because the slightest additional heating at the bottom, or cooling at the top, will unstabilise it until fresh convection currents have mixed it up again.

When convection currents first start up at the bottom of a bath, the warmed water only rises far enough to meet water of its own temperature; it is too heavy to penetrate the still hotter water above, which acts as a "lid" to prevent it rising any farther. So the layer of convectional turbulence is only of limited thickness at first. But with further heating at the bottom, this convection layer continues to thicken as its increasing temperature enables it to absorb more of the "lid," until finally convection is going on through the whole depth of the bath.

Now, what bath-water can do, so can the atmosphere. A mass of air can be either stable or unstable; if well stirred up it is on the verge of instability, and a layer of convection currents can be built up by heating of the ground. Only in this case the ground is not heated from below, but from above. The sun's radiation can pass through dry air without appreciably affecting it, but on striking solid earth the radiation at once takes effect. The heated ground then communicates its heat to the air immediately above. When this heated air starts rising, a convection layer is built up in which the air is mixed by convectional turbulence.

But here we come to the big difference between air and water: a well-mixed layer of water has the same temperature throughout, but a well-mixed layer of air has not. As a mass of air rises, there is less of the atmosphere to press on it from above, so it expands. But in expanding it becomes colder, in accordance with physical law. Another mass of air, falling to take its place,

gets compressed by the increasing weight of atmosphere above, and the compression heats it. So in a turbulent layer of air, what goes up gets colder, and what comes down gets warmer, with the result that the layer is warmest at the bottom and coldest at the top.

If, when we go up through a layer of atmosphere, we find colder air the higher we go, then the *rate* at which the temperature falls, or "lapses," with increasing height, is called the *lapse rate*. This is one of the most important terms in the soaring pilot's vocabulary.

In the case of a well-mixed layer of dry air (air in which no cloud is formed), the rate of cooling with increasing height is between 5·4 and 5·5 degrees Fahrenheit per 1,000 feet of height (in metric measure 1 degree Centigrade per 100 metres). It is conveniently remembered as "5½ degrees per thousand feet."

The rate at which an ascending mass of air will cool off as it rises, provided that it does not lose heat to, or gain heat from, its surroundings, is called the *adiabatic lapse rate*; the word "adiabatic" indicates that there is no transfer of heat. The rate for dry air, 5½ degrees per thousand feet, is called the *dry adiabatic* lapse rate. (*Adiabatic* is pronounced with the first *a* and *i* long and the rest short; the first and fourth syllables are accented). While a well-mixed layer of water, therefore, has no temperature lapse, a well-mixed layer of air has an adiabatic lapse rate.

Remembering this difference, we can now apply the lessons of the bath to the atmosphere. Starting with a layer of air 1,000 feet thick, well mixed by turbulence, and therefore 5½ degrees colder at the top than at the bottom, we now *either* apply heat at the bottom *or* cool it still more at the top. As with water similarly treated, this renders it unstable, but the result in this case is to increase still further the temperature difference between top and bottom; the difference now becomes 6 or 7 degrees, or more, which is greater than the adiabatic rate of 5½, and is therefore called a *superadiabatic* lapse rate.

Vertical currents are now to be looked for, as in an unstable layer of water. But whereas water at the bottom of an unstable layer starts rising because it is less dense than the water above it, this is not so with air.

In an unstable layer of air, the lowest part has the heaviest weight of atmosphere pressing upon it, so is denser (unless

extremely hot) than air higher up; no portion of it will start rising till something disturbs it, like a gust of wind, or being flung against a proturberance, or getting a push from adjacent colder air. But once a mass of air starts rising from the bottom of an unstable layer, it will continue to rise because it will then be warmer than its surroundings. This is because it cools at the adiabatic rate of 5½ degrees per 1,000 feet while rising through air that has a greater lapse rate than this; for instance, after it has gone up 1,000 feet its surroundings have become perhaps 6 or 7 degrees colder, but the rising air has cooled only 5½ degrees and so is warmer and lighter than the air around it at that height.

Such a mass of rising air is called a thermal convection current, or *thermal* for short. It will continue to rise until either its heat is dissipated by mixing or it is brought to a stop by penetrating a stable layer. Thermals will be discussed in greater detail in the next section, when cumulus clouds are described.

Now to return to our well-mixed layer of dry air with an adiabatic lapse rate. If it is 1,000 feet thick, it must be 5½ degrees warmer at the bottom than at the top. Let us now render it stable by either cooling the bottom or warming the top, which will of course reduce the temperature difference, and the lapse rate will be less than 5½ degrees—perhaps 4, 3, or less. Any air which is made to rise through this will cool at 5½ degrees per 1,000 feet rise, find itself colder than its surroundings, and try to get down again. In other words, in stable air vertical currents tend to be damped out; and this damping action is stronger the more stable the air.

For there are degrees of stability. A layer can be made more and more stable by continued warming at the top or cooling at the bottom. The process can continue until the lapse rate is reduced to nothing, and the result then is an *isothermal layer* in which the temperature does not change with height.

The atmosphere as a whole, up to the border of the stratosphere, is subject to a moderate amount of convection and is mildly stable, having an *average* lapse rate of a little over 3 degrees per 1,000 feet; the actual rate varies greatly at different heights, places and times, according to the weather.

The stratosphere, which starts at about 7 miles high in temperate countries, is an isothermal layer; there is no convection

in it, and it forms a lid which convection currents cannot penetrate from below.

If we take an isothermal layer and make it still more stable, we produce a layer which is coldest at the bottom and warmest at the top; the usual temperature difference is inverted, and the condition is known as an *inversion*. This is another particularly important word.

An inversion is often found on top of a convection layer, acting as a "lid" above which the air is smooth. If the inversion layer is thick, or its top is much warmer than the bottom, it is called a *strong inversion*. If thin, and with little temperature difference, it is a *weak inversion*, and is liable to be penetrated by any particularly vigorous thermal.

On clear nights there is usually a strong inversion close to the ground, which cools down by radiating its heat away into space.

We have, then, three different kinds of stable layer:

(1) With a less-than-adiabatic lapse rate, more or less stable, according to whether the rate is small or large;
(2) An isothermal layer, very stable;
(3) An inversion, exceedingly stable. (This is the only kind of stable air that resembles a stable layer of water in being warmer above than below).

There is only one sort of unstable layer: that with a super-adiabatic lapse rate. Well above the ground it is impossible to have a lapse rate much above the adiabatic, because convection sets in and destroys it. But the nearer the ground we get, the more viscosity comes into play, and the greater the lapse rate can become before convection starts up.

For instance, at noon on a sunny day at midsummer in England, the air at 1 inch above the ground is nearly 4 degrees (Fahrenheit) warmer than at 1 foot, and 5·7 degrees warmer than at 4 feet. (The "ground temperatures" reported by meteorological stations, by the way, are measured at a standard height of 4 feet above the ground, and so ignore this intensely overheated layer). This rate of decrease of temperature with height is, of course, very much more than the adiabatic rate; but any up-currents which start up at this level are very small and are soon slowed up by friction and dissipated by mixing. They are the cause of the "shimmering" of objects seen through them on a hot day.

This *superadiabatic layer* (as it may be called for short) extends upwards with lessening intensity till it merges into the "adiabatic layer" of large-scale convection above; from it the thermals in the adiabatic layer draw their supply of heated air. It will be mentioned several times in the next section.

We can now see how the lapse rate affects slope lift.

In very stable conditions the lowest part of the atmosphere is reluctant to rise; it will blow round a hill rather than over it, or through a gap in a ridge. But if forced to climb a hill, it will

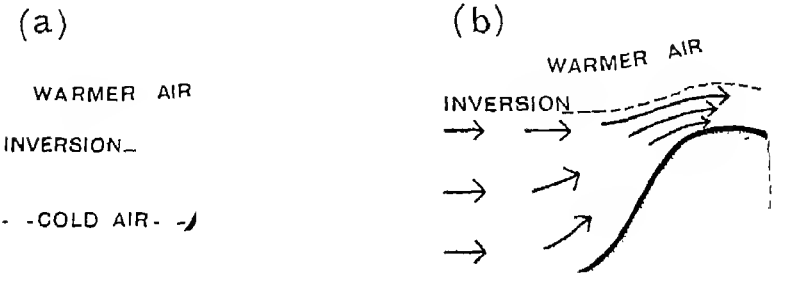


Diagram 7. *The influence of an inversion on slope lift.*

(a) With an inversion below the hilltop, only that part of the hill above the inversion is effective in creating slope lift.
(b) With an inversion above the hilltop, the wind speed up the slope is increased (and so is its vertical component), but the height to which the slope lift extends above the top is reduced.

try to squeeze over the top in a shallow stream, and consequently at increased speed (Diag. 7).

In unstable conditions, air which is blown up a hill will want to go on rising, so a thermal may go up at intervals, either from the slope or from the summit.

There is another way of stirring up a fluid, and that is by friction. Let us return to the water, take it out of the bath and put it in a river. As it flows over the rough river bed, the lowest part of it is stirred into eddies by friction against various irregularities. This kind of stirring is called *frictional turbulence.*

If the water is originally in a stable condition, this layer of frictional turbulence thickens gradually like a convection layer; but it takes up the average temperature of the water it has

absorbed, which is less than that of the yet unabsorbed warmer water above. So there is a sharp difference of temperature between the top of the turbulent layer and the bottom of the warm "lid" which lies upon it.

Air behaves similarly, except that the layer of frictional turbulence has an adiabatic lapse rate. Immediately above it there is an inversion, just as in the river there is a sharp change to the warm layer above the turbulence. The inversion is a direct result of the thickening of a layer of frictional turbulence; such an inversion is not produced by convectional turbulence, and, if present, must have been there beforehand.

In stable air, as already stated, vertical currents tend to be damped out; and as frictional eddies include vertical currents, albeit small ones, they tend to be damped out too. In unstable air the opposite occurs; eddies tend to persist and even to grow.

It takes a strong wind to stir up a stable layer, such as an inversion, near the ground, and convert it into an "adiabatic layer." Under average conditions, a wind of at least 22 m.p.h. (10 metres per second) is needed to "destroy an inversion," as the process is called. But it takes a very much stronger wind to destroy its opposite, the unstable "superadiabatic layer," which exists near the ground on days when there are thermals about.

It is to be noted that when a layer of air has been well mixed by frictional turbulence during a windy night, any warming-up of the ground after sunrise will render the whole layer unstable, so that convection, as soon as it starts, can spread throughout the layer. It follows that turbulence in the lower atmosphere on a windy day is usually a combination of both frictional and convectional turbulence.

A layer of cold air next to the ground, with a well-defined boundary separating it from warmer air above—or, in other words, with a strong inversion just above its upper surface—behaves rather like a liquid under the influence of gravity. It will flow downhill and collect in a hollow, or pile up against an obstruction and then pour over the top; also, waves can be created at its surface by the less dense air above blowing across it.

In the late evening and early night, under a clear sky, the ground cools down rapidly, and so does the air in contact with

it, as already explained. Where this ground is sloping, the cold air flows down, owing to its density, as a shallow stream which has been named a *katabatic wind.* Normally, when air descends, it is warmed at the adiabatic rate, but in a katabatic wind this warming is prevented by its continued contact with cold ground; so the contrast between it and the general atmosphere, which is usually warmer at lower levels, is increased and the katabatic flow gathers strength as it proceeds. The cold air may collect at the bottom of the slope as a deepening "pool," gradually displacing the warmer air which was there before.

This rising of the displaced warmer air has been held responsible for the so-called *evening thermal*, an extensive and very smooth up-current sometimes found above a slope after sunset when there is insufficient wind to produce slope lift. However, for the displaced air to rise fast enough to lift a sailplane, the cold "pool" would have to fill up at the rate of several feet per second, and this rate could not be maintained for the hour or more during which the "evening thermal" may persist. An alternative explanation by Georgii is that, although the lowest part of the atmosphere cools down in the evening, the air at a height of several hundred feet or more is still in an unstable condition, and convection can be set going in it by any disturbance such as sudden lifting due to the presence of a hill below. And Lange explains the "evening thermal" by suggesting that, since the cold air has drained off into the valleys, the higher air, which has an adiabatic lapse rate, can be rendered unstable by encountering those features on high ground, such as woods, which still retain the heat they have accumulated during the day.

The opposite to a katabatic wind is an *anabatic wind*, which flows up a heated slope in the day-time. As the air goes up, continued contact with hot ground prevents it from being cooled adiabatically, thus increasing the contrast between it and the general atmosphere, which is cooler at higher levels. This effect is particularly strong over steep-sided mountains in calm weather; elsewhere it is responsible for a general tendency of thermals to go up from high ground, though if the slope is gentle the anabatic wind may break away before it reaches the top, and go vertically upwards as a thermal. In windy weather the anabatic effect helps to reinforce slope lift over a slope which faces the sun.

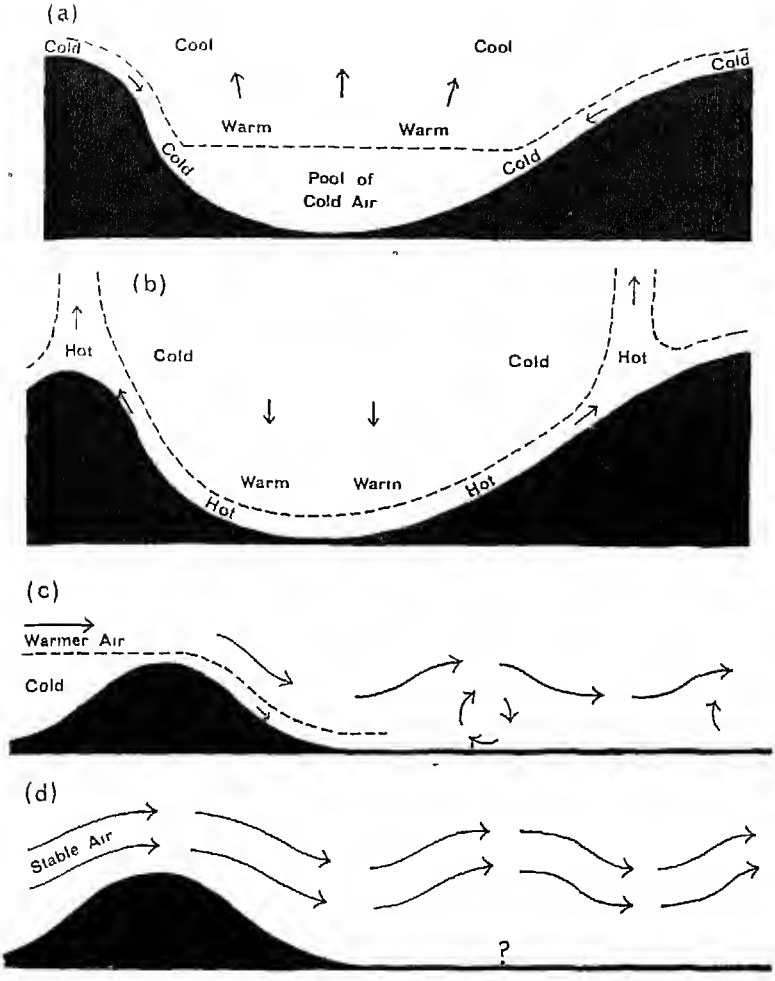


Diagram 8. *Some further effects of temperature stratification in hilly country.*

(a) *On clear nights the ground radiates heat away into space and cools the air in contact with it; the cold air runs downhill by gravity and displaces warmer air upwards out of the valley.*

(b) *On a sunny day the air heated by contact with hot ground tends to rise from hills or hillsides, where it is warmer than the adjacent cooler air at the same level.*

(c) and (d) *Wave motion is easily set up in a flow of stable air, thus providing a series of up-current zones to leeward of a mountain. In most cases investigated, where sail-planes have used such up-currents, the air-flow is as shown in (c), the initial impulse being downwards, and a series of eddies being formed below each wave crest. However, in theory, waves should also be formed when conditions are as shown in (d), where there is no inversion, and the initial impulse is upwards.*

Waves

Waves on the surface of a comparatively cold layer of air can be of two kinds, like those on a water surface: moving waves occur when wind blows over water, and stationary waves are set up when water flows over a submerged obstacle.

In air, moving waves occur when there is relative motion between the air layers above and below an inversion. The greater this relative motion, the longer is the wave length; but the greater the temperature (*i.e.* density) difference at the inversion, the shorter is the wave length. One probable example of soaring in such a wave has been recorded by J. W. S. Pringle, who maintained height for 7 minutes on a day when wave-like domes in the haze horizon were observed at that level, the ground wind underwent periodic fluctuations, and an inversion 3,000 feet thick showed a difference of 19 m.p.h. in speed and 30 degrees in direction between the winds at its top and bottom.

Stationary waves, on the other hand, have been extensively used. In a *standing wave*, as it is called, the up-current retains its position over the ground, so the sailplane can either hover over one spot; or, if the wind is not strong enough for that, move to and fro above a strip of ground lying at right angles to the wind direction, just as in slope-soaring.

A train of standing waves is set up by an obstruction such as a mountain ridge lying transverse to the wind direction, provided that the atmosphere is markedly stable. Where warm air overlies cold, the cold air piles up to windward of the ridge until it is high enough to pour over the top. The warm air, therefore, approaches the ridge across this piled-up cold air, and undergoes no marked upheaval as it reaches the ridge. Next, the cold air cascades down the lee slope of the mountain, and the warm air falls down on top of it, rebounds up again, descends once more, and continues to move alternately up and down in a series of undulations which gradually die out. The wave crests extend laterally, parallel to the ridge, and lie at equal intervals downwind of it.

The epithet "warm," applied to the wave-forming layer, refers only to the contrast between its lower levels and the colder air just underneath; owing to its lapse rate the wave-forming layer will itself be cooler at higher levels. Its actual lapse rate is of the greatest importance; the more stable it is,

the more easily will the wave motion be propagated upwards through the layer. By remaining in the upward-moving air to windward of a wave crest a sailplane can continue to climb through the stable layer; and if the stability extends to the border of the stratosphere, so can the sailplane reach that level, provided the lift is strong enough. The stratosphere itself is even more stable, and in theory it should take part in the wave motion with increased amplitude; in practice, however, no sailplane has yet climbed through the stratosphere, though soaring flights have been made in standing waves to leeward of the Alps which may have reached its lower border.

In some instances there is found a large stationary eddy near the ground, directly beneath the crest of each standing wave, causing a reversal of wind direction at ground level. A sailplane can use the upward-moving side of this eddy to climb into the wave system above.

Even in the absence of a low-level inversion with cold air below, a train of standing waves can still be set up in a stable layer of air, which in this case is first thrown upwards by the obstructing ridge, producing slope lift there, before moving downwards over its lee slope.

As with moving waves, the wave length (*i.e.* distance from one crest to the next) of standing waves is increased by a strengthening of the wind, and a sailplane pilot must be prepared for a displacement of the up-current region due to this cause. A wave train may cross an established soaring site, in which case the slope lift can be either extended or curtailed according to whether it coincides with the upward or downward flow of a wave; this depends on the wave length, and therefore on the wind speed, which is, of course, subject to variation. A decrease in stability (*i.e.* steepening of lapse rate) also increases the wave length but reduces the amplitude, and with an adiabatic lapse rate no waves are produced.

In practice the best results in soaring have been attained with wave lengths of the order of 5 miles. At shorter lengths, theoretically, the wave train forms with more difficulty; and with a wave-length of $1\frac{1}{4}$ miles or less, the first wave "breaks" and no train is set up. In other words, the phenomenon is at its best in strong winds. But much more investigation is needed, both in theory and practice, before the subject of standing waves can be fully understood.

Clouds

It is possible for a limited amount of water vapour to mix with air and yet remain in the form of an invisible gas. When this limit has been reached, and the air includes as much water vapour as it can hold in gaseous form, it is said to be *saturated.* This limiting amount varies with the temperature: hot air can hold more water vapour than cold air. It follows that, if we take a mass of air which is already saturated, and then cool it down. it will not be able to hold as much water vapour as before. The surplus vapour then ceases to be a gas and *condenses* into droplets of water, or—if below freezing point—into crystals of ice.

If these visible particles of water or ice remain suspended in the air, they are called cloud. And if they grow big enough to fall rapidly through the air, then they become rain or snow. But if they condense directly on to cold solid objects, they form dew or hoar frost.

To produce cloud, air must first become saturated, either by cooling the air or by adding more water vapour to it; then the saturated air must be further cooled, whereupon some of the water vapour, which it can no longer hold, condenses as cloud. The commonest way in which air is cooled is by being lifted; we have already seen that dry air cools 5½ degrees during every 1,000 feet of ascent. if no heat is removed or added to it from outside. Air can also be cooled by contact with cold ground or a water surface, and if any cloud results it is called *fog*, which is the name for a cloud resting on the surface of the earth.

The word *humidity* is used as a measure of the amount of water vapour in the air. Humidity can be measured in various ways, by weight, volume or "partial pressure"; but the most useful measure is that called *relative humidity*, which is the amount of water vapour actually present relative to the amount which would be present if the air were saturated. It is expressed as a percentage; so that, for instance, saturated air has a relative humidity of 100 per cent.

Since relative humidity is the relation between two quantities, it can be altered by changing either quantity separately. The amount of water vapour present can be increased by evaporation into it from a damp surface over which the air passes, or from raindrops falling through it. And the amount of water vapour which would saturate the air depends on the temperature, so it

can be altered by heating or cooling the air. Thus, if air with a relative humidity of 60 per cent is cooled gradually till it can only just hold its water vapour content, the relative humidity rises from 60 to 100 during the process; when this stage has been reached, any further cooling will cause some of the water vapour to condense. If the relative humidity is 80 per cent to start with, less cooling will be needed before the air becomes saturated and condensation begins.

In other words, the greater the relative humidity, the less the air needs to be lifted in order to cool it sufficiently to form cloud. For instance, air which starts from ground level with a relative humidity of 60 per cent will form cloud on reaching a height of about 3,000 feet; whereas a figure of 50 per cent gives cloud at about 4,000 feet.

Since clouds are formed by air being cooled, and the cooling of air is in most cases due to its being lifted, it follows that clouds are usually the result of up-currents, and can therefore serve as very useful signs to the sailplane pilot.

But there is another way in which clouds can help the pilot.

When water vapour condenses and turns into water droplets, the resulting liquid water is hotter than the gaseous water vapour from which it has been formed. This heat is quickly communicated to the surrounding air; it is called the *latent heat of condensation* and is described as being "released" or "liberated."

As already stated, rising air cools at the dry adiabatic rate of $5\frac{1}{2}$ degrees per 1,000 feet of rise, so long as it remains dry. But the time may come when, owing to continued cooling, the air becomes saturated; then, if it continues to ascend, cloud is formed, latent heat is released, and the air no longer cools at the dry adiabatic rate because of the liberated heat. It still cools as it goes up, but at a reduced rate known as the *wet adiabatic* lapse rate, which has an *average* value of about 3 degrees per thousand feet.

Unlike the dry adiabatic rate, which has always the same value, the wet adiabatic rate varies somewhat according to the temperature; this is because warm air can hold more water vapour than cold, so there is more of it to condense and more heat is liberated than when water is condensing out of cold air.

When cloud forms in an up-current, therefore, the ascending air is warmer than it would have been if no cloud had formed; in plain terms, the formation of cloud gives an extra boost to the up-current, and may even enable it to continue where it would otherwise have come to a stop.

Whether an up-current is suppressed or is encouraged to continue, depends on whether the air through which it passes is stable or unstable—that is, has a lapse rate less or greater than the adiabatic, as already explained. This statement refers to the dry adiabatic when the up-current remains dry; but if cloud is forming in the up-current, then the question whether it stops or continues is dependent on whether the air outside has a lapse rate less or greater than the *wet* adiabatic. If the actual lapse rate in the atmosphere is between the dry and wet adiabatic, *e.g.* 4 degrees per 1,000 feet, then the atmosphere is stable with respect to dry up-currents within it, but unstable with respect to up-currents in which cloud is being formed. Air in this condition, with a lapse rate between the wet and dry adiabatic rates, is said to be *conditionally unstable*, because it only becomes unstable on *condition* that cloud begins to form within it. Instability with respect to dry up-currents tends to be destroyed rapidly by mixing due to convection. Conditional instability, however, can exist to quite a marked degree as long as no cloud is formed.

Descending air becomes warmer as it descends. If dry, it is warmed at the dry adiabatic rate of 5½ degrees for every 1,000 feet of descent. The descent of a cloud, consisting of water particles surrounded by saturated air, also causes a warming of the air within it. But the warmed air can then hold more water vapour than before, and this is supplied to it by evaporation of the cloud particles. Evaporation, which is the opposite process to condensation, uses up latent heat, and the descending air is therefore cooler than it would have been in the absence of cloud; instead of being warmed at the dry adiabatic rate during its descent, it is warmed only at the wet adiabatic rate, which has an average value of about 3 degrees per 1,000 feet change in height, as already stated.

The evaporation of cloud in a down-current thus gives an extra boost to the down-current, just as an up-current is boosted by the formation of cloud within it.

Convection Clouds

Although a cloud is usually the result of an up-current, the lift is not necessarily strong enough to raise a sailplane. Furthermore, the cloud may persist for a time after the up-current has ceased. The usefulness or otherwise of a cloud to a sailplane pilot must be judged by its shape and by the changes it is undergoing, and this is no easy matter.

A cloud which grows in volume is still being fed by its up-current. If formed in conditionally unstable air it grows upwards; but if it meets stable air it grows outwards, once the upward impetus has been exhausted. But when the up-current has ceased, the cloud gradually disappears by evaporation; this is done either by mixing with the surrounding drier air, or by descending and so being warmed.

The clouds which form in the tops of thermal currents are called *cumulus*. Their typical feature is a dome-like summit, this being the shape of the upper border of the rising current. Often there are many of these rounded protuberances on the upper surface of the cloud, and their number is a good guide to its actual size. Comparing this with the *apparent* size, one can estimate roughly the cloud's distance.

The height at which a cumulus cloud begins to form depends on the temperature and humidity of the air in the thermal when it starts up. As these are approximately the same for all thermals in the same district at any particular time of day, it follows that all the cumulus clouds visible at one time are at about the same height at the level of their bases, which is the part of the cloud where condensation begins. This height is called the *condensation level*, and it can be calculated if the temperature and humidity at ground level are known.

Humidity is determined by comparing the reading of an ordinary thermometer ("dry bulb") with that of a "wet bulb thermometer" which is cooled by evaporation from a wet rag wrapped round the bulb containing the mercury; then either looking up the result in published tables, or taking a reading from a special instrument, the Cloud Base Predictor, devised for the purpose by J. S. Fox.

Since water vapour is distributed fairly evenly throughout the thermal, condensation level is at about the same height in all parts of it, so that the base of a growing cumulus cloud appears flat when seen from the side. Actually, the thermal is often

hottest in the centre, so the relative humidity is less there and cloud base is a little higher in the middle than at the edges; but this fact is only apparent to a sailplane pilot flying close under the cloud.

At condensation level the cloud does not start to form instantaneously, but gradually as the rising air approaches and reaches saturation point. The base of a growing cloud is there-

Fig. 29. *A small cumulus cloud showing dark against the sun, which throws its shadow on the surrounding haze. Note the ill-defined flat base at "condensation level," showing that air is still rising into the cloud.*

fore ill-defined, especially at close quarters. A milky haze can sometimes be seen near condensation level before the cloud has actually begun to form, especially in hazy weather. In fact, in exceptional conditions a thermal can sometimes be recognized by its haziness quite low down.

In contrast to the growing portion of a cloud, the melting portions usually disintegrate into shreds which show a remarkably hard but ragged outline.

Cumulus clouds differ individually, but tend to conform to certain average characteristics. It will be best to describe a typical cumulus first, and then show what conditions cause a departure from the average.

The life-history of the cloud commences with a pre-natal stage. First, a small mass of heated air starts up from near the ground, either because some disturbance has already raised it into cooler aerial surroundings, or because it has passed over ground which is hotter than other ground near by. The rising air continues to draw after it more air from the superadiabatic layer, for perhaps five or ten minutes, and then the supply stops, probably because cooler air has replaced it. The resulting mass of rising air—that is, the thermal—may be regarded as something between a stream and a giant bubble; it may have a height

Fig. 30. *Thermals may occasionally be visible in the form of haze. In this case, cloud has begun to condense at one point.*

of 3,000 feet, a width of 500 to 1,000 feet, and be going up at a rate which has reached perhaps 3 feet a second after the first 400 feet of ascent, and thereafter accelerates to 5 or 10 feet per second—but these are average figures and subject to much variation.

When the upper border of the thermal has reached condensation level at, say, about 4,000 feet, a cumulus cloud begins to form, and the latent heat of condensation causes an increase in the up-current. For five minutes or so, the cloud continues to grow as more of the thermal reaches the 4,000 foot level and

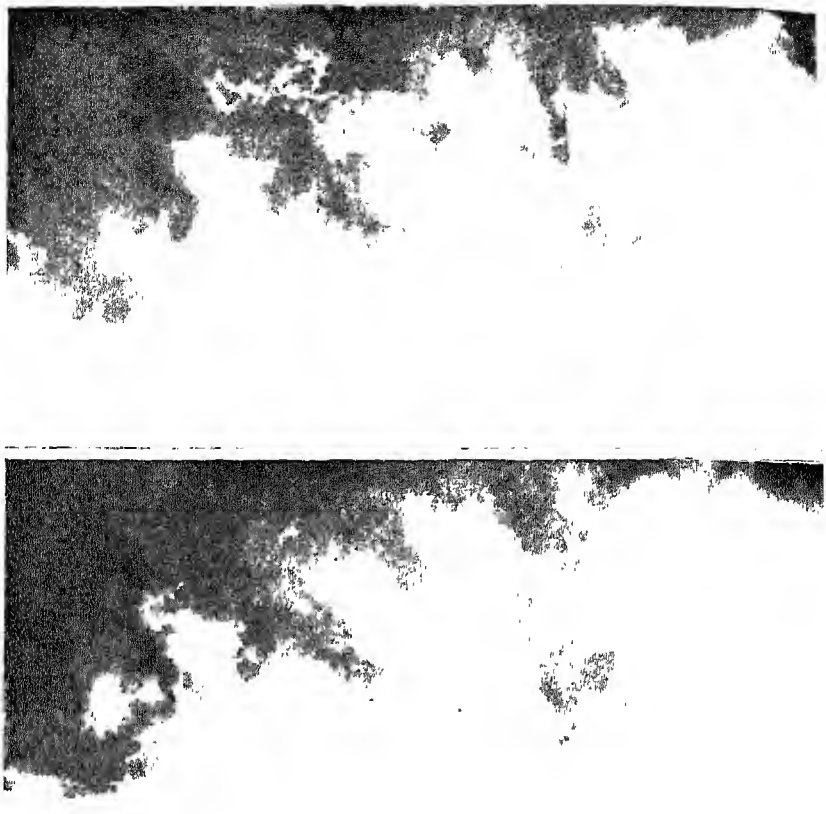


Fig. 31. *Two successive views of the edge of a large cloud seen directly overhead. Comparing the two, it will be observed that the cloud is disintegrating, and the raggedness of its edge should be noted.*

becomes saturated. Then, for perhaps another five minutes, one part of the cloud continues to be fed by the up-current while the rest is pushed aside and begins to disintegrate. Finally, the cloud takes about ten minutes more to evaporate completely, while the up-current has ceased and may be replaced by a down-current of less intensity. So, after some 10 minutes' climb by the thermal in dry condition, the visible life of a cumulus cloud works out at about twenty minutes.

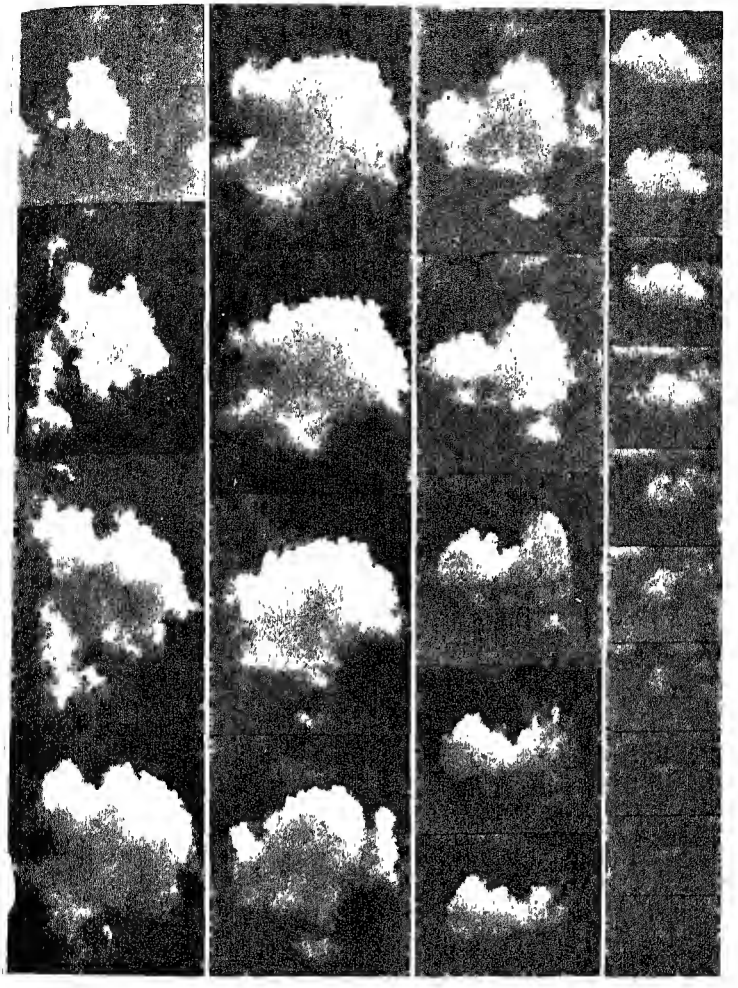


Fig. 32. *The life-history of a small cumulus cloud, shown in twenty-three photographs taken at intervals of one minute. Notice that, when the right-hond portion has begun to disintegrate, the cloud is still growing on the left.*

It follows, therefore, that of all the cumulus clouds seen in the sky at one time, only about half are of any use to the sailplane pilot, while an equal number of invisible thermals are likely to be on their way up to form more cumulus clouds.

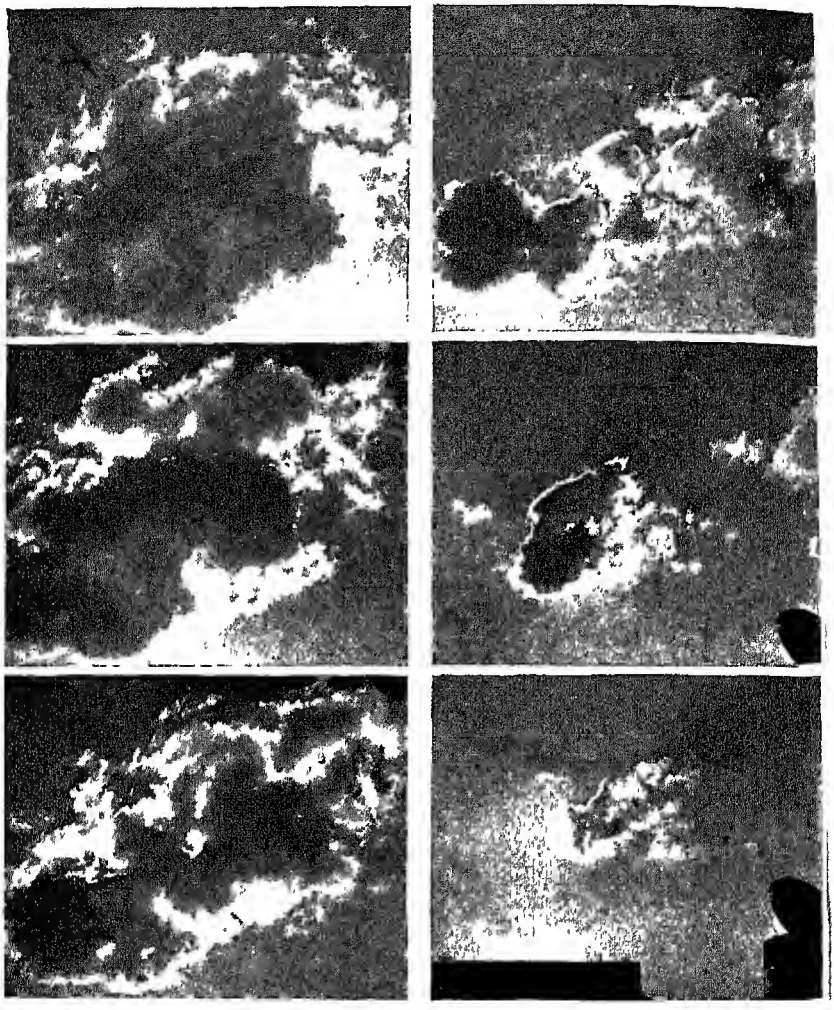


Fig. 33. *Six views of a disintegrating cloud, taken at intervals of three minutes. Note the hard raggedness of the disintegrating portions.*

Also, since any cloud he is using will eventually lose its updraft current, and he will have to leave it for another, he must, in choosing where to go next, be able to distinguish a growing cumulus from a dying one. Unfortunately, this has proved a most difficult task, though much experience can be gained by

observing the clouds from the ground, deciding what stage each of them is at, and then watching patiently to see if one has guessed right. It is equally difficult to decide whether a newly-born cloud is going to attain full size, or will melt away without growing any bigger, as often happens.

We must now discuss how the typical conditions described above can be modified.

Firstly, by wind. In calm or light winds the position from which a thermal starts up is decided chiefly by the contrast in temperature between different kinds of ground which have been warmed by the sun. Loose soil gets hotter than compact soil, which conducts more of the heat downwards. Dry soil gets hotter than wet soil or vegetation, which needs to absorb more heat for a given rise of temperature. A slope facing the sun gets hotter than level ground, and that in turn is warmer than a shaded slope. A thermal starting from a cornfield can draw on an extra supply of heated air imprisoned among the corn. But for these contrasting areas to act as the deciding factor in stronger winds, they must be large enough, or at least sufficiently elongated in the wind direction, to give them time to take effect on each portion of air as it hurries across their surface.

A wind also brings another factor into play. The "super-adiabatic layer" can then be started on its upward journey by being blown against an obstruction, such as a belt of trees. Obstructions are particularly likely to decide the place of origin of thermals if no marked contrasts of ground heating have disturbed the uniformity of the layer.

A strong wind may be so turbulent that small portions of the superadiabatic layer are continually breaking away to start on their upward journey. There is then no chance for a large quantity of heated air to collect before going up, except over sheltered ground in the lee of a hill. The thermal that goes up from such a sheltered region, or "wind shadow", is known as a *wind-shadow thermal.*

A further effect of wind is that due to the velocity gradient, or increase of wind speed with height. This causes a column of rising air to be bent over at an increasingly oblique angle; and when a cumulus cloud forms in its top, the cloud also leans over in a direction away from the wind. The top of the cloud moves ahead of the base, after which it usually starts descending;

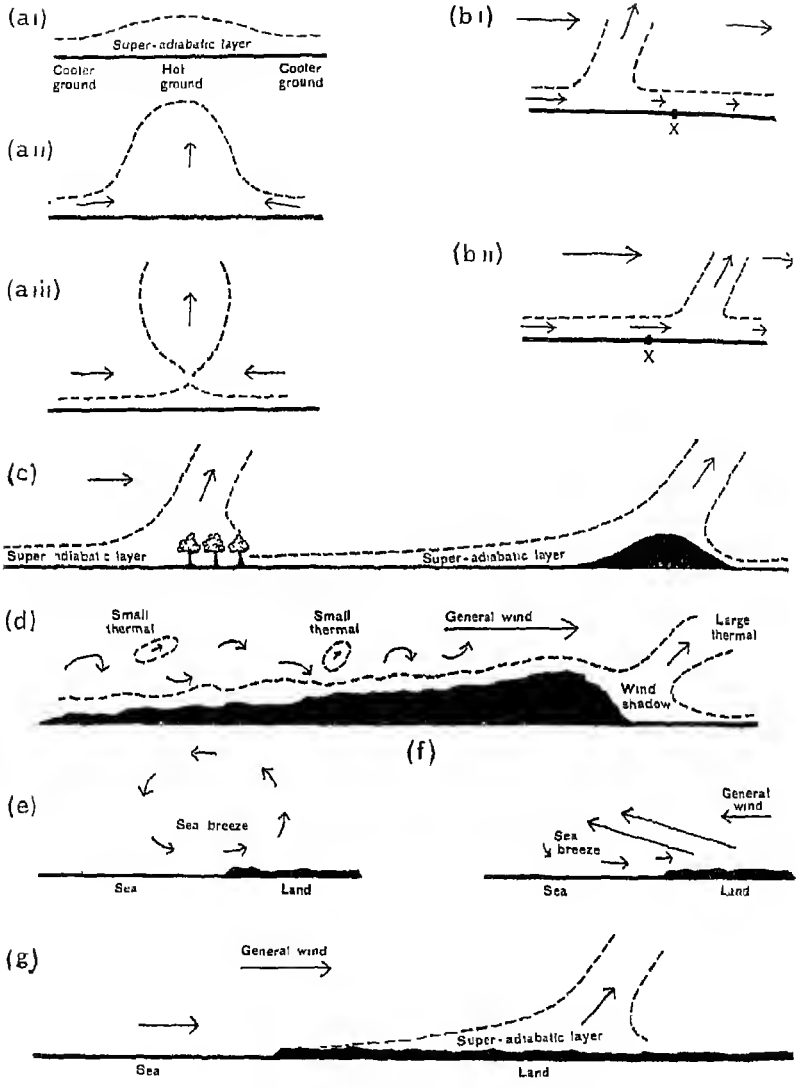


Diagram 9. *The release of thermals from ground level.*

(a) Shows the start of a thermal due to contrasts in ground heating. (i), the super-adiabatic layer becomes intensified locally, (ii), it starts to rise and draws in more heated air from around, (iii), it is released from ground level, and colder air flows in to take its place.

(b) The root of a thermal current often travels with the wind. As it passes, the wind is modified owing to the drawing-in of air to feed the thermal. At a given point X, the wind speed is reduced as the thermal approaches (i), and increases as it departs down-wind (ii). If the thermal passes to one side, the wind is diverted towards it

in fact, the cloud takes on a rolling motion, with the down-current in front and the up-current behind, and looks like the topmost segment of an otherwise invisible wheel. Owing to the slope of the up-current, that part of it which has not yet reached condensation level is to be sought up-wind from the cloud.

Sometimes the rising column is bent over so far that it breaks into separate portions which go up independently, so a series of small clouds is formed, one behind the other, at intervals of a minute or two, each cloud lasting only a few minutes. So, in a short row of small cumuli, the rearmost is the one to pick on.

Once cumulus clouds have begun to form, the effect of their shadows has to be reckoned with. Ground in bright sunshine gets hotter than shaded ground, and as thermals tend to go up from where the contrast is greatest, they may be expected near the edge of the shadow. A body of comparatively cold air collects in the shadow just above ground level, travelling with it and scooping up the sunlit air in front, thus creating a thermal whose origin travels at the speed of the shadow, which is that of the wind at cloud level.

The season of the year influences the average height of cloud base, which is lower in winter (though seldom below 2,000 feet) and higher in summer (seldom above 6,000); it is also lower in high latitudes and higher in the tropics.

Cumulus clouds also change according to the time of day, and in several respects. Usually they form at gradually increasing heights as the moisture, at first concentrated near the ground, gets distributed through the convection layer, which at the same time becomes gradually warmer; both these effects reduce the relative humidity at ground level.

The average time at which they start forming—about 10 a.m. local time—is not much earlier in summer than in winter,

(c) Another effect of the wind is to cause the release of the superadiabatic layer where it meets an obstruction.

(d) In strong and turbulent winds, small thermals break away before they can build up to a large size, particularly over rough ground, except over a sheltered lee slope where larger thermals can form

(e), (f) and (g) show the position of lift due to the so-called "sea breeze" which blows in coastal districts in the daytime, due to the land being heated more than the sea. In calm weather (e), the lift should be expected directly over the coast. With a wind blowing from the land the lift is found over the sea, up to a mile or two off-shore. In a general wind blowing in from the sea, the lift is found farther inland the greater the contrast in temperature between land and sea.

although at the latitude of England, for instance, there is more than four hours' difference between summer and winter sunrise. This is because in summer there is a greater contrast between night temperatures on the ground and the temperature in the convection layer, so that the sun, after rising, takes longer to convert the ground inversion into a superadiabatic layer warm enough to start the thermals.

The first thermals to break away from the ground tend to be small but to go up fairly fast. The air which they push out of the way often descends as a down-current round the edge of each thermal to fill in the space in its wake. If the air above the superadiabatic layer has been well stirred by convection the day before, its lapse rate is already steep and the thermals soon reach up through it to cloud level, forming small cumulus clouds. On a windy day these small clouds are ragged and are called *fracto-cumulus*. Later on, the thermals are bigger, and larger clouds are formed, the largest size usually being found in mid-afternoon.

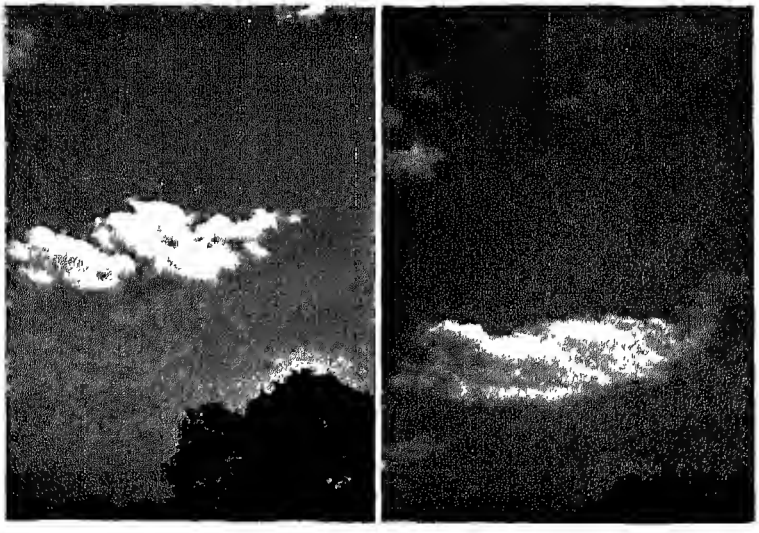


Fig. 34. *Two views of flattened cumulus, taken on the same day ; the first when it was newly formed, and the second a little later, showing its full development. It is kept flat by the presence of an inversion just above it. After mid-day, the condensation level had risen to the inversion and no more cloud could be formed.*

The earliest clouds are limited in thickness by the size of the thermals which feed them. But after mid-day, cloud evolution is very much dependent on the lapse rate of the atmosphere at the height to which the cloud tops have grown. Under what may be termed usual conditions, the convection layer is surmounted by an inversion at about 6,000 or 7,000 feet. If the cloud top reaches this level before it has finished growing, then it will spread sideways; and if the condensation level rises so far as to approach the inversion, then the clouds are thin and flat, or they may be represented by only a few wisps, in which case the thermals slow up before reaching them.

Cloud Distribution

It is often found that flattened cumulus clouds tend to last longer than the taller and narrower variety, and that the compensating down-currents are more evenly spread over the areas between the clouds. In its extreme form, this arrangement leads to the establishment of a regular pattern of semi-permanent vertical currents throughout the convection layer; the pattern is made up of units of approximately equal size and spacing known as *cells*. In calm or light winds, each cell consists of a

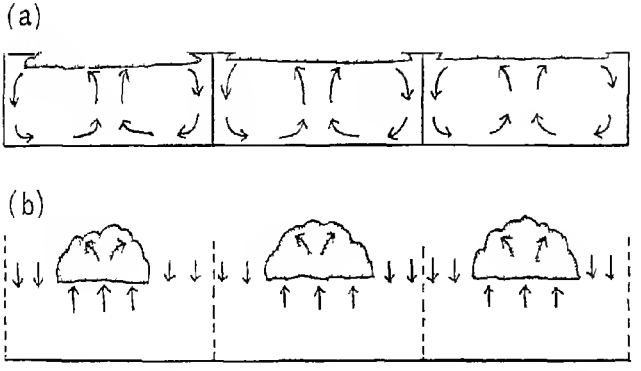


Diagram 10. *The vertical oir motion in a series of convection cells is theoretically as shown at (a), which will serve as vertical section through strato-cumulus, alto-cumulus or cirro-cumulus, according to the scale. A cross-section through a group of parallel cloud streets is shown at (b), with the usual vertical currents to be expected, though they are not olwoys so regularly distributed as shown here.*

central up-current, surrounded by an area of down-current which merges with the down-currents of adjoining cells.

This arrangement can be reproduced artificially on a small scale, and is also found very frequently in such cloud sheets as are divided into separate cloudlets, in which each cloudlet marks the top of an up-current. In theory, such cells should be more than twice as wide as they are thick. Cumulus clouds, however, are rarely as uniformly placed as this, though they usually tend to a certain average of size and spacing.

In a wind, several types of cell are possible. C. S. Durst has observed cells in which the up-current is at the rear, while the down-current is at the front, following closely behind the up-current of the next cell; the top of each cell is capped with a small cloud of the "roller" type already described. Each cell has a length about equal to its height, and is bent over by the wind.

Sir Gilbert Walker and Prof. D. Brunt, on the other hand, conclude from small-scale experiments that a wind should cause an elongation of the cells, transverse to the wind direction in moderate winds, and parallel to the wind if it is strong; the corresponding cloud patterns consist of long rolls of cloud, transverse or parallel to the wind respectively. Such transverse rolls are rarely seen, but long strips of cloud parallel to the wind are frequent and are known as *cloud streets*, because a sailplane pilot can soar along the corresponding belt of up-current in a straight line, as along a street, thus covering much distance in a short time.

Cloud streets are made use of in a large proportion of cross-country soaring flights. The term is used not only to describe a continuous belt of cumulus-type cloud, but also for any row of detached or semi-detached cloud units strung out in approximately the wind direction. It seems doubtful, however, that the "cell" theory can account for all examples, because they occur as frequently in moderate as in strong winds, and are not unusual in light winds on days when the cumulus clouds are rather flat.

A short street can be formed when thermals repeatedly go up from the same spot, which they may do at intervals of the order of fifteen minutes. The individual clouds of such a street are evanescent, but Mrs. Ann Douglas has suggested that their shadows induce the formation of a second street, and that this then induces a third, and so on; in fact, the process is cumulative.

CLOUD STREETS

Fig. 35. A street of separate cumulus clouds, moving from right to left in a W.N.W. wind. In the far distance can be seen another street, which has not subdivided into separate clouds.

Fig. 36. A continuous street, which nevertheless shows traces of subdivision into separate units. It is moving from left to right in a W.S.W. wind. A parallel street can be seen beyond it. On the right is some high cloud which shows a streakiness parallel to the wind direction.

Fig. 36. A typical sky-full of cloud streets. The view is easterly, more or less down-wind. It will be seen that the streets are not exactly parallel, as they do not all converge towards the same point on the horizon.

Cloud streets usually last much longer than isolated cumulus clouds. It seems probable that their life-history is influenced by the position of their shadows, which, of course, changes in the course of the day with the angle of the sun. Thus a street should persist if located above sunlit ground, but if it lies overhead of its own shadow, or that of an adjacent street, its life would be short. If in an intermediate position, the up-current might be confined to one side of the street—a circumstance sometimes found by sailplane pilots.

Occasionally, pilots have found "streets" of thermal lift at a low level without any clouds above them to mark their position. And at times they have found lift in clear air beside the cloud street, above the expected condensation level.

The *amount* of cumulus cloud in the sky is important; obviously the more there is, the less sunshine is available to heat the ground. Also, the release of latent heat, due to clouds forming, warms the top of the convection layer and therefore renders the whole layer more stable. So a surfeit of clouds is self-destructive, because it inhibits the convection which produces more cloud. But when it has melted away for this reason, there is then a surfeit of clear sky; convection is encouraged, and another lot of clouds appears.

The amount of cloud, does, in fact, often fluctuate with a periodicity of about half an hour, which, it will be remembered, is the average length of life of a cumulus cloud plus its pre-natal thermal. Fluctuations of great amplitude—between almost complete overcast and almost clear sky—have been reported from small plains adjoining mountainous country.

In spite of these variations, there is a certain mean cloud amount appropriate to each day's atmospheric conditions, and this can be estimated before the clouds begin to form.

R. M. Poulter assumes that the drier the surrounding atmosphere is, the faster the clouds evaporate into it. So he finds that the amount of cloud to be anticipated is proportional to the relative humidity of the atmosphere at the level where clouds are expected to form; thus, a humidity of 50 per cent results in a half-clouded sky.

S. Petterssen points out that the surrounding air sinks to compensate for the cloud up-currents, and that the more stable this air is, the more will its descent stabilise the convection layer and hinder the formation of fresh cloud. He states that, if the

dry air at cloud level has a lapse rate only a little steeper than the *wet* adiabatic, the cumulus clouds are small with large spaces between; but if its lapse rate is nearly as steep as the *dry* adiabatic, the clouds fill a considerable portion of the sky, and large and small clouds coexist.

G. Kimble and R. Bush recommend taking the relative humidity at ground level *when the first trace of cumulus appears*, dividing it by 6, and then subtracting 6; the result gives the expected amount of cloud in tenths of sky covered. By this rough-and-ready method a half-clouded sky should be expected from a relative humidity of about 66.

An overcast sky is, in fact, to be expected if much humidity in the air leads to a low cloud base, well below the top of the turbulent layer. This happens whether the turbulence is convectional or frictional—it may be both. If convectional, the early cumulus clouds soon join up into a continuous layer known as *strato-cumulus*. The convection currents which maintain this cloud are weak, in the absence of sunlight, and may or may not be able to lift a sailplane.

If turbulence which is frictional, or mainly so, gives rise to a cloud sheet, it is more uniform in texture than strato-cumulus and is called *stratus*. Its preliminary stage consists of ragged bits somewhat resembling fracto-cumulus but flatter and smaller. These are called *fracto-stratus*, and mark the position of narrow localised up-currents.

Stratus cloud is also found over high ground where humid air is blown up the slope to such a height that it rises above condensation level. Or it may only attain the fracto-stratus stage, in which case the bits of cloud show a slope-soaring pilot where he can find extra lift.

Another kind of stratus is formed when fog begins to lift. This often breaks up, at a few hundred feet only, into shapes resembling small cumulus; they can be distinguished from real cumulus by their fluffiness and high *apparent* speed (both due to nearness) and by the fact that the sun is easily seen through their grey portions. Occasionally they undergo gradual transition, with increasing height, into cumulus.

Unstable Cumulus

So far we have considered states of the atmosphere in which the upward growth of cloud is limited by the presence of an

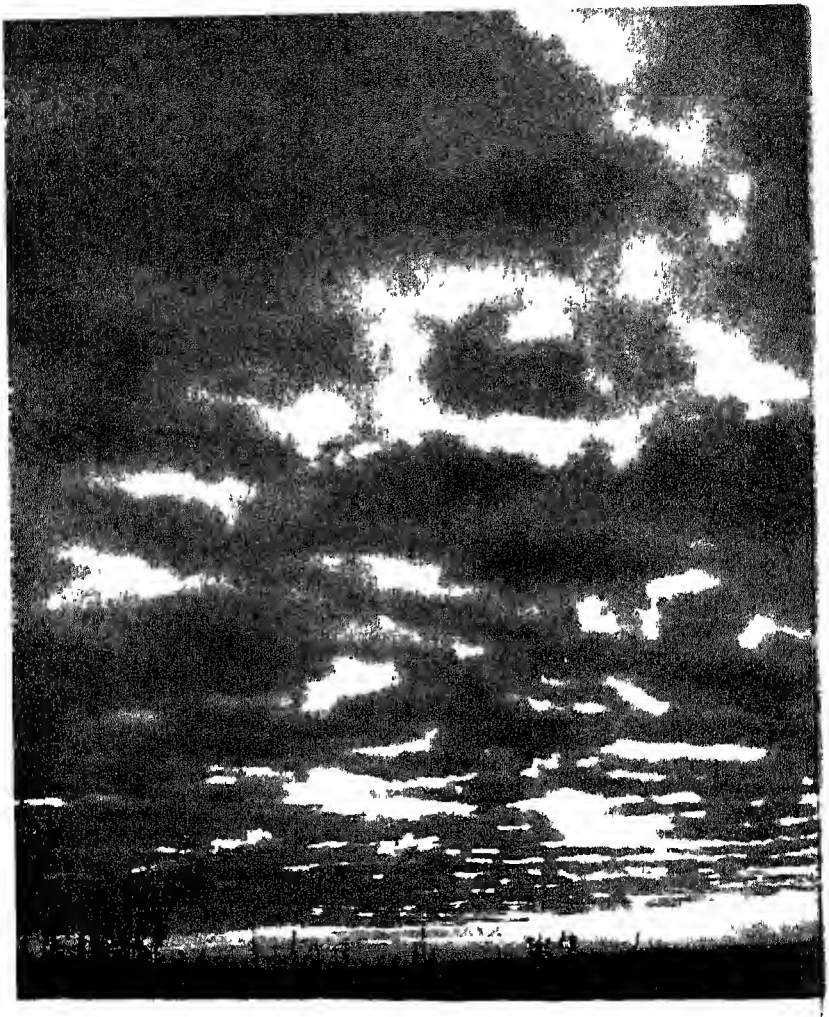


Fig. 38. *A sheet of Strato-Cumulus. It is divided into a pattern of "cells" of roughly equal size.*

inversion a few thousand feet up. But what happens if the up-current causing the cloud is not stopped at this level?

The inversion may be so weak that the cloud tops penetrate it; or there may be no stable layer at all, but a conditionally unstable atmosphere up to a far greater height. Clouds, once formed, are then stimulated to grow to an extent which depends

on how unstable the atmosphere is and how much water vapour is available for building them up.

In these conditions, a thermal of limited volume may produce a tall and comparatively narrow cloud, with down-currents around its sides, and, if it is already well-grown, no further thermal lift below it. Greater instability or humidity may cause the cloud to grow to enormous size, since the latent heat of condensation induces a further up-current area below it, in addition to the original thermal. Such a cloud-induced up-current is called *cloud-lift*. (This term is also applied to the extra boost given to a thermal when cloud forms in its top, and also to the up-current within the cloud).

A large and fast-growing cumulus cloud pushes up the air above it, and a sailplane pilot who has climbed to a great height in one cloud can then glide across the tops of lower ones and make use of this lift. The pushed-up drier air may even reach its own condensation level and form a sort of cloud-cap just above the cumulus top, which then usually rises through it and turns the cap into a scarf. This "cap" is a useful sign of strong cloud lift which promises to continue for some time.

The lift below very large cumulus masses is not equally distributed, and may be absent in parts. The strongest lift is usually found at the darkest part of the base, above which the cloud is thickest. On a windy day such clouds often take on the same rolling motion as is found in smaller cumuli, and the best lift should then be at the rear, particularly if that part of the cloud slopes away from the wind.

A large mass of cumulus may grow big enough to produce rain or snow, and, if bigger still, thunder and lightning, sometimes accompanied by hail. Shower clouds and thunderstorm clouds are called *cumulo-nimbus*. They reach their fullest development later in the day than cumulus clouds, apparently because of the time it takes for a large-scale pattern of convection currents to develop. These clouds have a definite life-history, much longer than that of cumulus.

At first an exceeding complex mass of domes is seen, visibly growing if watched for even a fraction of a minute, and of a rock-like hardness in appearance because, if a side-view is possible, the cloud must be so far off that the usual woolliness of cumulus is no longer apparent. When it has risen so far as to have become cooled below freezing-point, its texture changes;

CUMULO-NIMBUS

Fig. 39. *An early stage of Cumulo-nimbus. The cumulus is growing to great size and the domes are becoming more complex. The cloud is receding towards the east*

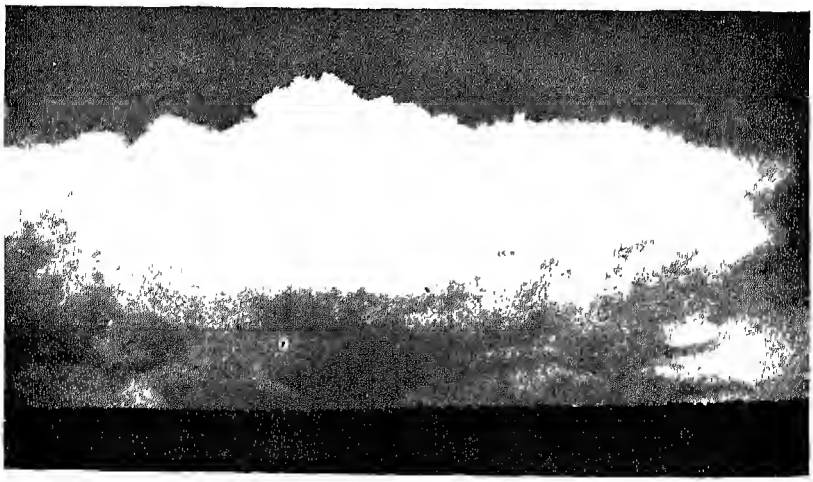


Fig. 40 The "frozen" top of a **Cumulo-nimbus**, *showing the fibrous outline and smoothing-out of the complexities of the domes. Towards the right the characteristic "anvil" shape is already beginning to appear The cloud is receding eastwards*

the hard outline becomes fuzzy and fibrous and the complexities of the domes are smoothed out. Because of this it no longer looks as far off or as big, and if all but this "frozen" portion is hidden by low cloud, it may look deceptively near and small and a pilot may not realize, before taking off, that there is cumulo-nimbus about. The best clue to the recognition of a frozen cumulo-nimbus top is its "pearly" appearance, as if one were looking through its surface well into the interior.

At this stage of its growth, a cumulo-nimbus contains violent vertical currents, both up and down. If the down-currents descend to the cloud base they may cause festoon-like bulges on its under surface, known as *mammato-cumulus* and looking like cumulus domes turned upside-down. This cloud type is a useful sign of the presence of cumulo-nimbus when no other good view can be obtained; it also warns the sailplane pilot of the presence of down-currents near by, which have been known to reach a speed of 20 ft. per second.

At this same stage of cumulo-nimbus development, snow forms in the topmost frozen portion, collects water from the surrounding cloud particles, melts as it descends and turns to rain. At first its descent is delayed by the up-current, and no rain can fall through an up-current of more than 27 feet per second, because any raindrop big enough to fall faster than that will be broken up by the rush of air. (This breaking up, by the way, is responsible for the electric phenomena.) Any rain lifted back into the freezing area turns to hail, and if this happens repeatedly the hailstones can grow to large size.

Rain falling from the cold upper regions of the cloud cools the air through which it falls, so in time a down-current is created, and the cloud base is lowered owing to the combined cold and humidity. A lowered cloud base in parts is another sign by which cumulo-nimbus can be recognized from below. This down-current, after descending to earth, may rush outwards and prise up the air outside the cloud, creating an up-current, usually in front of the cloud.

As for the frozen top of the cumulo-nimbus, it usually continues to climb until at last it reaches a stable layer, perhaps at 15,000 or 20,000 feet or more, after which it spreads sideways and becomes flattened on top. The resulting shape resembles that of an anvil, the name by which it is commonly known. This "anvil" usually remains for some time after the cumuliform

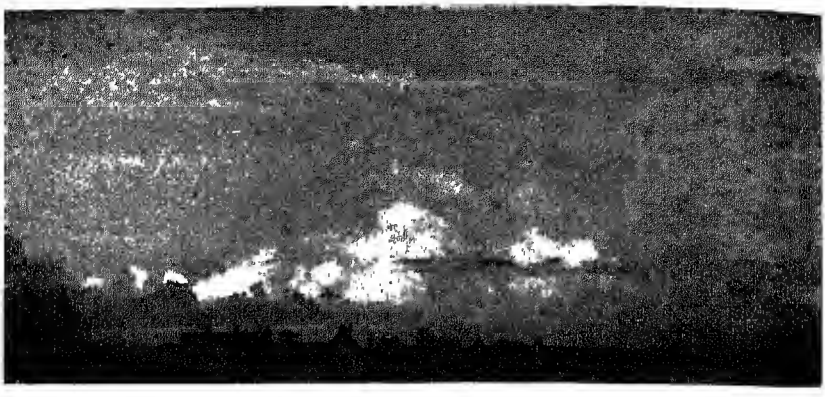


Fig. 41. *A huge complex mass of Cumulus, growing into Cumulo-nimbus. It has a rack-like appearance, because of its distance. In front are some strips of Stratus, another characteristic feature. In the background is a still more enormous "anvil", belonging to a more distant shower at a later stage of development; the anvil has begun to turn into Alto-Cumulus along its edge.*

Fig. 42. *Mammata-Cumulus; an unusually well-developed example. Downward bulges show the presence of down-currents.*

lower portion of the cloud has dispersed. The cumulo-nimbus, however, may disintegrate in one part and yet continue to develop in another part by the growth of fresh cumulus.

Other Cloud Forms

Finally, there are types of cloud which do not draw their moisture directly from ground level, but nevertheless are of interest to the sailplane pilot.

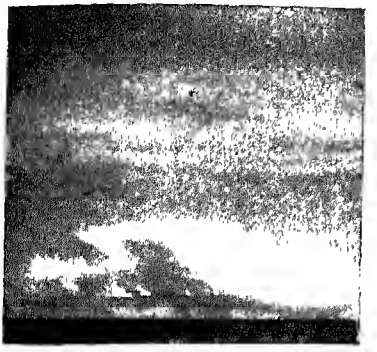


Fig. 43. *An April shower in the distance. The cloud is comparatively small for a cumulo-nimbus, and consists largely of "anvil".*

Small cumuli can form in a turbulent layer above a ground inversion, according to K. Lange, the turbulence being started up by waves at the surface of the inversion.

A strato-cumulus layer usually shows a pattern of cells of too small a size for it to be likely that their associated currents reach far below the cloud. In spite of this, a convection layer may exist below, and in it cumulus clouds may form, underneath the strato-cumulus. If there is much instability at the cumulus level, the cumulus may penetrate the strato-cumulus and protrude above it. Farther up still, the air may on occasion be so unstable that cumulus, once having reached it, continues to grow, and may even turn to cumulo-nimbus, whose presence can only be surmised by the darkness of the strato-cumulus base underneath it—until the rain arrives.

From about 7,000 feet up to heights at which water droplets can still exist unfrozen, a sheet of cloud subdivided into a pattern is called *alto-cumulus*. A continuous sheet at similar

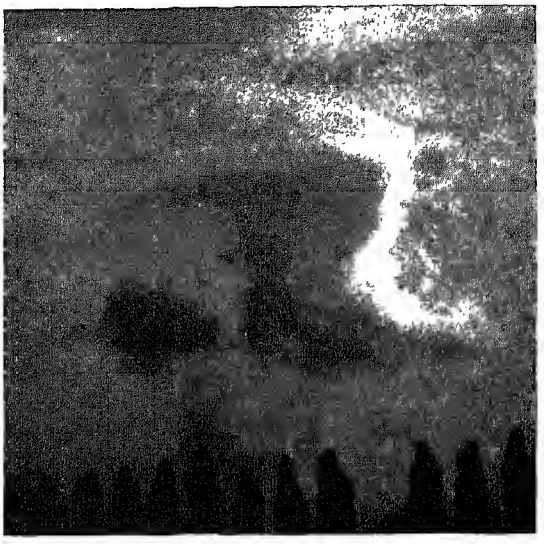


Fig. 44. *A cumulus cloud, showing dark against the light, has grown so high as to penetrate the layer of stroto-cumulus. The shadow of its invisible top, cast on the stroto-cumulus, is seen just to the left of the cloud.*

heights is called *alto-stratus*. At its thickest, strato-cumulus can consist of great rolls of cloud, but alto-cumulus is much less thick; on the other hand, there is no limit to how thin either type can be. Alto-stratus, however, can have a thickness of many thousands of feet. Alto-cumulus is less dense than strato-cumulus, as less moisture is available at that height; also, the cloudlets are smaller—in fact, the apparent size of the cloudlets is the official criterion for distinguishing the two types.

The up-currents forming the "cells" of alto-cumulus are usually too weak to lift a sailplane. But there are two exceptions.

When the air just above the alto-cumulus is particularly unstable, each cloudlet grows upwards and comes to resemble a miniature cumulus cloud with a dome-shaped top, though without a flat base, except that sometimes a row of such cloudlets projects upwards from a thin, flat strip of cloud forming a common base to them all. This type is called *alto-cumulus castellatus*; an alternative English name is "turret cloud." An up-current of 40 feet per second was once found just below such clouds.

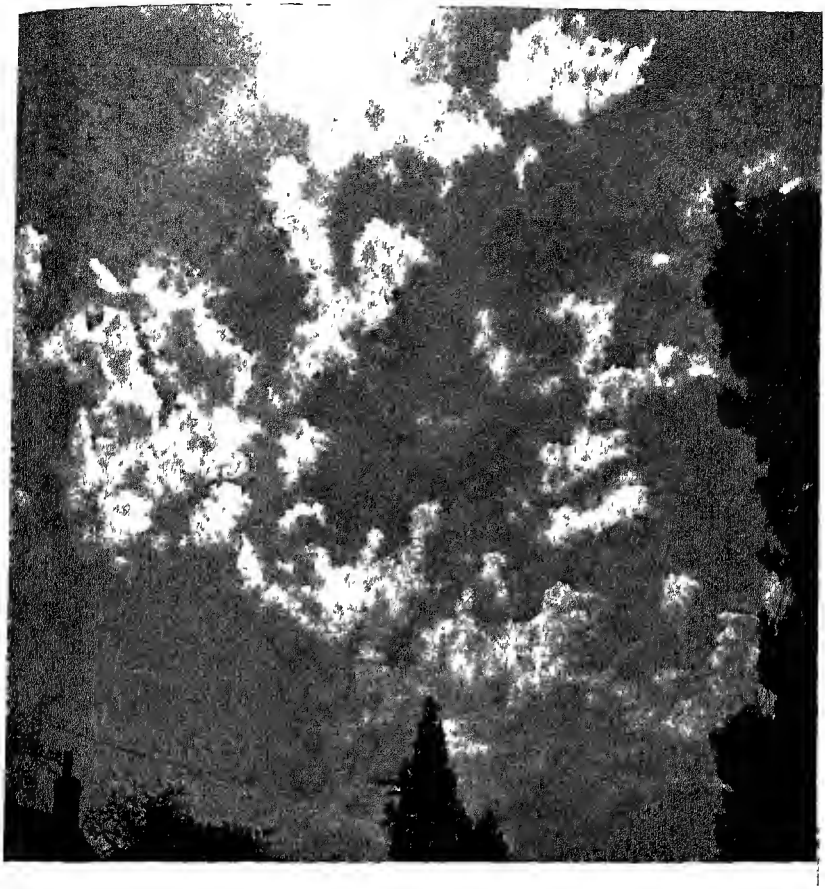


Fig. 45. *Alto-cumulus castellatus. A typical example of the detached form. It also occurs in the form of a row of protuberances rising from a common base.*

The other type which can provide strong lift on occasions is known as *lenticular* cloud. It is lens-shaped in section, is usually extended in a direction transverse to the wind, and either remains stationary with the wind blowing through it, or travels less fast than the wind. It can, of course, only do so by continually growing at the windward edge and evaporating at the leeward edge; and if, as often happens, its edges are broken up into cloudlets, these cloudlets can be seen continually forming on the windward side, becoming swallowed up in the thickest

Fig. 46. *Alto-cumulus lenticularis to leeward of Cross Fell in the Pennines, where the famous "Helm Wind" creates standing waves suitable for soaring.*

part of the cloud, then emerging and dissolving again on the leeward side.

It is obvious from their character that these clouds form the visible tops of air waves of the sort described in the last section, either stationary or moving, and that they are a valuable sign for the sailplane pilot, who can expect to find the up-current below and within the windward half of each cloud, and often just outside it too.

Lenticular clouds are often formed in series, and at almost any level—sometimes, in fact, at more than one level simul-

taneously. Every type of cloud sheet can take on a lenticular form, and is then designated by adding the word *lenticularis* to the type name, as in *alto-cumulus lenticularis*, which is the most frequent variety.

The highest clouds are composed of ice crystals and have a characteristic fibrous appearance. For the sailplane pilot they are chiefly of interest for their prognostic value. If in isolated portions, they are called *cirrus*; this type can exist in a great variety of shapes, but is most commonly found in units consisting of a tuft with hairy streamers trailing away below. A special kind of cirrus is that formed at the top of a cumulo-nimbus cloud by freezing of the cumulus tops, as already described.

A sheet of cloud at the cirrus level is called *cirro-cumulus* if subdivided into a pattern, and *cirro-stratus* if in a continuous sheet. Cirro-cumulus is often arranged in parallel bands, a mile or more apart, and it is reasonable to suppose that the shadow pattern of these bands can induce the formation of cloud streets at a lower level. Some of the bands may be composed of cirrus or alto-cumulus.

Sheets of high cloud intercept some of the sun's radiation, though less effectively than low cloud sheets; when they are only patchy, a pilot on a cross-country flight can avoid their effects by making a detour. At night, extensive sheets of cloud hinder the cooling of the ground by intercepting the outgoing radiation and reflecting it back to earth; again, low sheets do so more effectively than high. It is well to remember, when studying the finer details of lapse rates in the lower atmosphere, that radiation can be absorbed and given out not only by clouds, but to a less extent by water vapour.

One more cloud type remains to be mentioned: *nimbo-stratus*, the characteristic rain cloud of depressions, which will be described in the next section. Clouds which grow thick enough to produce rain are called "cumulo-nimbus" or "nimbo-stratus" according to the type from which they are evolved.

Weather

A sailplane pilot wants to know how different types of weather affect the wind, clouds and thermals. Let us first dispose of the one situation in which all three are likely to be absent: the centre of an area of high pressure ("high" meaning large in

amount). Pressure is measured by the barometer, and is proportional to the weight of atmosphere above. An area of high pressure is called an *anticyclone*, to distinguish it from its opposite, which is known as a depression but used to be called a "cyclone" (a term now applied only to a tropical revolving storm).

High Pressure

A large anticyclone of the sort found in temperate regions goes through a definite life-history. As pressure builds up, the air within it slowly subsides. To study the effect of this subsidence, let us go back to our analogy of water in a bath. We must imagine the bath to be expansible sideways, so as to increase its area and cause the surface of the water to sink to a lower level. If the water was stable to start with—warm above and cool below—the warm and the cool are now brought nearer together and the water becomes more stable, because the temperature increases more quickly for a given increase in height.

It is the same with the atmosphere. If a body of air is squashed from above, it becomes more stable, provided that it started with a lapse rate less than the dry adiabatic. In subsiding air, even a state of conditional instability vanishes in time, so that cloud formation is suppressed; furthermore, the air has descended from regions where it can hold little moisture, so it is relatively dry. If the process continues long enough, even thermals are suppressed too, because they cannot compete in temperature with air which has been heated adiabatically by descent from a far higher level.

After a time the anticyclone begins to decay; pressure falls off, subsidence stops, and stability of the air is reduced so that eventually convection starts up again. It is not unusual for a summer anticyclone to end with an outbreak of thunderstorms.

Anticyclones usually move slowly or stand still, though the smaller ones tend to move faster and show less intense stability phenomena.

Light winds suitable for out-and-return soaring flights are best sought somewhere between the too windy outskirts and the calm but too stable centre of an anticyclone.

Wind Direction

Winds, which are started by differences of pressure, are absent in the central region of an anticyclone, where the pressure is

uniformly high. Farther out, however, the pressure falls off increasingly; the wind therefore increases too, and round the edges of the anticyclone it can blow quite hard.

But after the first impulse the wind does not blow directly from high to low pressure regions; it is deflected owing to the effect of the earth's rotation, which works in the following way:

The atmosphere goes right round the earth every twenty-four hours, in company with the earth's surface below it. This motion is fastest at the equator and is less nearer the poles, so that a wind blowing from the equator polewards carries some of this equatorial momentum with it, overtakes the earth below, and appears to an earthly observer to be deflected eastwards—that is, to the right in the northern hemisphere and to the left in the southern. Conversely, air blowing from pole to equator lags behind and is deflected westwards. Further, any portion of a line of latitude is rotating in space, and a wind blowing parallel to it resists this rotation, with the effect that, again, it is deflected to the right in the northern hemisphere and left in the southern.

The ultimate result of these deflecting forces is that the wind is turned through a right angle, so that it no longer has high pressure behind it and low in front, but blows with the high pressure on the right and low to the left in the northern hemisphere, and *vice versa* in the southern.

It is customary on a weather map to draw lines of equal pressure, called isobars, which show very clearly the distribution of high and low pressure. It is also obvious, from the foregoing remarks about wind deflection, that every wind is forced ultimately to blow parallel to the isobars, so that the isobars on a weather map give in addition an excellent picture of the winds. For instance, around the central region of an anticyclone the isobars form concentric rings, indicating that the wind circulates round it in a clockwise direction in the northern hemisphere, and anti-clockwise in the southern.

The wind blows faster where pressure differences are more abrupt—that is, where the isobars are closer together and the barometric gradient is steeper; its speed can be calculated, and a wind of the calculated speed, blowing parallel to the isobars, is known as the *gradient wind.* This term was introduced in the first section of this chapter, where it was stated that the gradient wind is usually found at about 2,000 feet, but below this height it is slowed up by friction, especially near the ground.

The wind near the ground differs from the gradient wind not only in speed but in direction also: instead of blowing along the isobars it drifts obliquely across them, away from high pressure and towards low pressure. This means that, in the northern hemisphere, the wind direction at ground level is to the left of the gradient wind. The wind direction therefore changes with height, the *rate* of change being called the *direction gradient*, just as the rate of change of wind speed with height is the velocity gradient, as explained earlier. Close to the ground, the velocity gradient is much more in evidence than the direction gradient; farther up, both gradients are most pronounced in stable air, but are reduced when the air is being well mixed by convection.

The *average* difference in direction between the gradient and ground-level winds is 30 degrees; but in most good soaring conditions it is less. At greater heights above gradient winds, if they are southerly or westerly, the wind direction is still farther to the right; but northerly and easterly winds are often overlaid by a westerly wind high above.

When gauging the day's prospects from the early morning wind, a sailplane pilot should allow for a slope wind blowing to the left of what the wind direction is seen to be at cloud level; whereas the gradient wind, in which most of a cross-country flight will be done, is to the right of the wind direction low down as shown by a weathercock. (To find the precise wind direction in the clouds, do not look across wind, but up or down wind, or compare their motion with a fixed object overhead.)

The wind direction having been determined by the pressure distribution, and its strength by the pressure gradient, the sailplane pilot wants to know what kind of air it will bring—how stable and how humid—and this depends on its past history. Every mass of air can be traced back to some region of the earth where the atmosphere is almost stagnant, and as it will have remained there long enough to acquire certain characteristics, there is no need to go any further into its past. These regions are mainly around the poles and in the tropics and sub-tropics, and air which has come from these sources is called *polar air* or *tropical air* according to its source.

Polar air, in moving towards the equator, finds itself continually over a warmer surface than before; so it is warmed from the bottom and an unstable layer is created there. This

layer grows in thickness until convection has spread upwards throughout the whole mass, giving it a dry adiabatic lapse rate as long as no clouds form.

Tropical air, moving polewards, passes over a colder surface and is stabilised at the bottom, but the stable layer grows comparatively slowly in thickness. So, in considering the large-scale air streams, we find that cold air is likely to be unstable and warm air stable—just the opposite to the small-scale diurnal changes, in which the air is cool and stable at night and becomes unstable as it is warmed up in the day-time.

Humidity is influenced by two factors. Assuming that no moisture is added or removed, the warming of the polar air on its journey reduces its relative humidity, and the cooling of tropical air increases its relative humidity. Secondly, the air will have picked up additional water vapour after crossing the ocean, but not if it has approached across a continent. So each kind of air has to be qualified as either *maritime* or *continental*. This distinction introduces the further complication that the continents are hotter than the sea in summer and colder than the sea in winter, so that continental air tends to instability in the warm season and stability in the cold season.

The above principles serve as the main guide to inferring the soarability of the air from its past history. The chief remaining factor is the time of day: on land, night and day temperatures differ most in clear weather and least in cloudy weather, most in summer and least in winter; much recent rain also reduces the difference, because sodden ground can neither be warmed nor cooled as quickly as dry ground. Day and night have a negligible effect on the sea surface, which only undergoes a slow change of temperature with the seasons.

An important local modification is that a range of mountains, lying across the wind direction, deprives maritime air of much of its moisture by heaving it up and causing its water vapour to condense into rain. The air cools at the wet adiabatic rate as it goes up, and warms at the dry adiabatic rate (which is greater) as it comes down again; this leaves it warmer than it was before, and incidentally, stable enough for its descent to set up standing waves over suitable terrain. A "foehn wind" contains air of this type.

The prevailing *south-westerly wind* of the British Isles has usually come a long way without much change of direction, in

which case it brings "tropical maritime" air. It arrives in a moist condition and is stable up to a height of many thousands of feet, except in so far as the lowest layer has been well mixed by frictional turbulence up to, perhaps, 2,000 feet or less. On striking hot land in the day-time in summer, it becomes unstable at the bottom and convection spreads quickly through the layer of frictional turbulence and then more slowly to greater heights. Much low cumulus is formed, without growing to cumulo-nimbus unless it stays over land a long time; although a range of mountains will heave it up and produce voluminous cloud and rain, after which it will be drier but probably still produce cumulus. In winter it arrives colder, and therefore with a greater relative humidity, and stratus cloud often forms in the turbulent layer, but cumulus is less likely.

North-westerly winds almost invariably bring polar maritime air to the British Isles. During their passage over continually warmer seas, instability has been built up both by night and day and the convection layer has grown to great heights. Cumulo-nimbus may already have begun to form in it. On striking land in the day-time, its instability is immediately increased and thermals start up at once; cumulus is produced at a fair height, as the humidity is not great, and cumulo-nimbus is probable. After its passage across England, this air has become warmer than the sea, so on crossing the English Channel a thin layer of stability is formed, which, on reaching the Continent, has to travel some distance inland before it can be re-converted into a superadiabatic layer and start up the thermals again.

Because of the pressure distribution, polar maritime air often follows a curved course and arrives as a westerly, or even south-westerly, wind. On its final short south-westerly journey it may acquire a shallow stable layer at the bottom; but this is soon replaced over land by a convection layer which restores the polar maritime character of the air and allows cumulo-nimbus to develop.

This is an example of the principle that the original source of the air matters far more than its present wind direction.

A *north-easterly wind* usually brings polar continental air, but it approaches over the North Sea and there takes on some maritime characteristics. In early spring, when it is particularly common, it starts from frozen land in North-East Europe; then, in crossing the sea, which is less cold, it builds up a

convection layer thick enough to contain cumulo-nimbus clouds of no great height—the typical "April showers," which often consist more of "anvil" than cumulus. Later in the season the land is no colder than the sea; but when the air reaches Britain, convection starts up in the moist layer of frictional turbulence and may result in an overcast sky before mid-day, though farther west across England it probably clears enough to allow separate cumulus to form.

A *south-east wind*, if blowing round the border of a Scandinavian anti-cyclone, brings dry air from the Continent, cold in winter, warm in summer ("tropical continental"). If, in the latter case, pressure falls, thundery weather is probable, due to instability caused by a cool south-westerly wind high above the south-easterly; often, alto-cumulus castellatus coming from south confirms the presence of this high-level instability. On the other hand, a moist south-east wind, bringing increasing mugginess in summer or unusual warmth in winter, must have come originally from the south-west and been circulating round a depression, the approach of which it foretells.

Low Pressure

A *depression* differs from an anticyclone in several ways.

An anticyclone is an area of high pressure, calm in the centre; usually sluggish in movement, with settled weather, no sharp contrasts between adjacent parts, and air circulating round it in a direction giving east winds on the side nearest the equator.

A depression is an area of low pressure, with the strongest winds near the centre; usually rapid in movement, containing disturbed weather due to sharp contrasts between air of different origins, and an air circulation giving west winds on the equatorial side. In the northern hemisphere, therefore, the wind circulates anti-clockwise.

The slope-soaring pilot is concerned with the changes of wind as the depression passes over, the thermal-soaring pilot with the differing stability of the various kinds of air contributing, and the cloud-soaring pilot with what happens along the boundary between these different bodies of air due to their interaction.

The weather in a depression is essentially caused by the lifting of tropical air over polar air. The two kinds of air lie alongside at a boundary called the *polar front*, which goes right round the

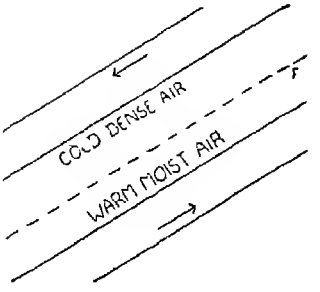
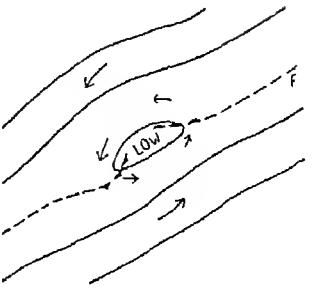


Diagram b



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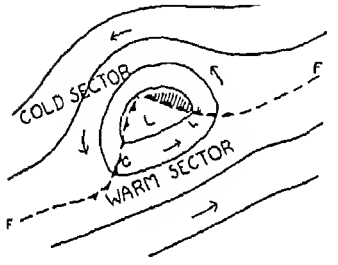

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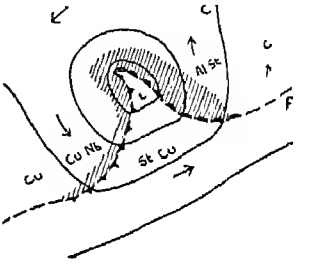


Diagram e

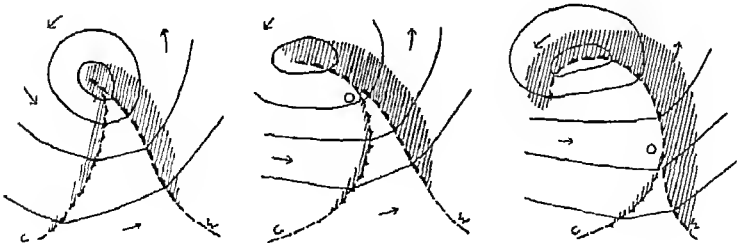


Diagram g

Diagram 11 *Depressions Diagrams b, c, d, e and g show successive stages of the life-history of a depression, as they would appear on a weather map The continuous lines are isobars, and the broken lines the Polar Front L is the centre of low pressure, W the warm front, C the cold front, and O the occluded front ot the point where the cold front hos caught up the warm and an occlusion is just beginning The shaded portion is the rain area*

Diograms f, h and j are vertical sections through the depression from west to east, on the equatorial side of its centre , the vertical scale is much exaggerated for cleorness Diagram f shows the pre-occlusion stage, h the onset of occlusion, j (1) a warm acclusion ond j (2) a cold acclusion

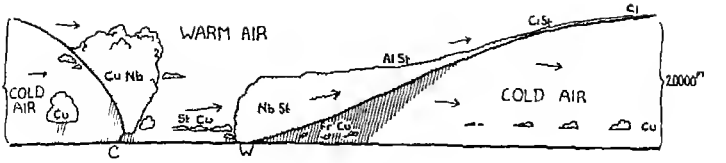


Diagram f

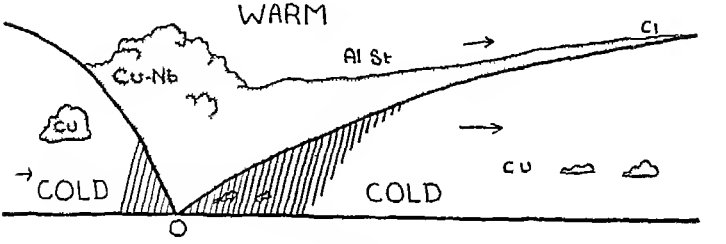


Diagram h

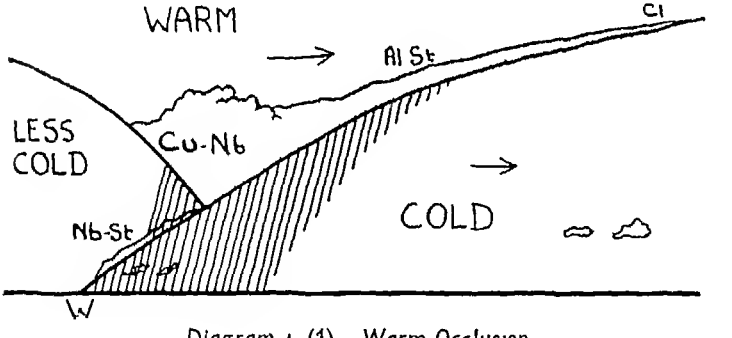


Diagram j (1) Warm Occlusion

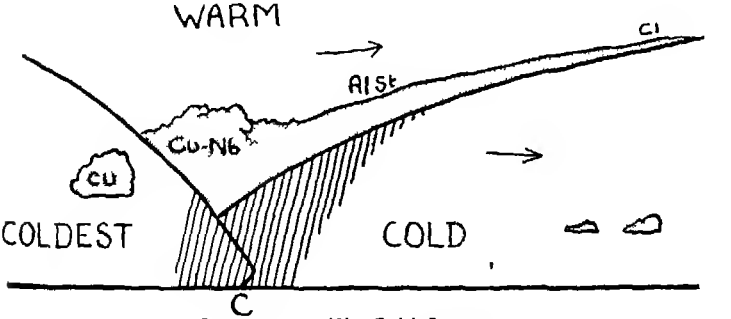


Diagram j (2) Cold Occlusion

earth at a high latitude in summer and a rather lower latitude in winter. The polar air approaches this boundary from the east, and the tropical air at a faster pace from the west; so there is relative motion, with the result that any kink in the polar front tends to grow like a wave, and to travel from west to east because the westerly air stream is the stronger. As a result of this "wave," a wide tongue of tropical air pushes into the polar air and starts climbing up over it. The polar air reacts by pushing towards the equator behind this tongue and then turning in under it from the west. In that way a depression is started.

A typical depression approaches from the west. The three signs of its approach are: falling barometric pressure, increasing high cloud, and (in the northern hemisphere) a freshening southerly wind (between S.E. and S.W.) carrying polar air northwards to make way for the tropical air coming from the west to replace it. The high cloud, which first appears as cirrus arranged regularly in rows, moving from west or north-west, is the first visible sign of the advancing tropical air, showing the highest point it has reached in its long gradual climb above the polar air in front of it. This climb causes most of the humid tropical air to become filled with cloud. After a time tropical air passes over which has not yet climbed so high, so its cloud base is lower and there is room for thicker cloud above. Any cumulus in the polar air below is gradually suppressed for lack of sun, plus the stabilising effect of the air being squashed from above. As the high cloud lowers, cirrus is replaced by white cirro-stratus, and that in turn, by grey alto-stratus, and finally, nimbo-stratus.

At this point the cloud base becomes indistinct; rain falls from it into the remaining polar air and saturates it, causing inky fracto-stratus (called "scud" by the sailors) to appear there. As the scud increases, rain reaches the ground, gradually increases in severity, and may continue for some hours. Sometimes, however, the air in the nimbo-stratus or alto-stratus above is unstable, probably due to its having originally left ground-level in the day-time, and the rain is then intermittent and showery owing to unseen cumulo-nimbus projecting above.

If the centre of low pressure is passing to the north of us, and if the depression is yet young, the next event is the arrival of the tropical air at ground level, with a change of wind to something like W.S.W. The advancing line along which polar

air makes way for tropical is called the *warm front*, because warm air replaces cold. A front is the boundary between two masses of air which have different characteristics due to their different life-histories.

The portion of a depression occupied by tropical air is called the *warm sector*. In it the rain usually ceases for a time but the sky probably remains overclouded. The air in the warm sector is stable, except that, farther south, it may be partially or wholly free from cloud, allowing a convection layer of limited thickness to build up, perhaps with cumulus.

After some hours the warm-sector cloud thickens again and rain recommences and becomes very heavy. Then, sooner or later, the lower clouds are noticed to have changed direction, moving at increased speed from west or north-west; soon blue sky appears in that direction, while the barometer starts rising. These phenomena mark the passage of the *cold front*, where tropical air is replaced by polar air, clear, cool and *unstable*, and its bracing effect is soon felt. When the sky has cleared, one can look back eastwards and see the retreating cold front clouds, a magnificent line of cumulus masses interspersed with torn-looking stratiform patches. Overhead, cumulus starts to form, and cumulo-nimbus is soon added to it, but probably becomes less frequent as time goes on.

If the warm-sector sky has been clear, the cold front may be seen approaching in the form of a continuous line of cumulo-nimbus stretching right across the sky. Since the cold air is lifting the warm air in front of it, this is the sailplane pilot's opportunity. But the warm air is not scooped up from ground level. Owing to frictional slowing-up of the lowest 2,000 feet of the atmosphere, the most advanced portion of the cold air forms a kind of tongue at 1,500 or 2,000 feet, entrapping the remnants of the warm air below it. At times, this moist, warm air escapes by rushing up in front of the cold "tongue," creating at that point a rapidly rotating roller of cloud known as a *storm collar*, which is one of the characteristics sign of a cold front. But as more warm air gets trapped, some of it shoots straight up into the mass of cloud above, through the cold tongue, which thus breaks down periodically and re-forms farther back. These escaping bits of warm air, which show themselves as uprushing dark shreds of cloud, can cause such extreme turbulence as to render a sailplane almost uncontrollable.

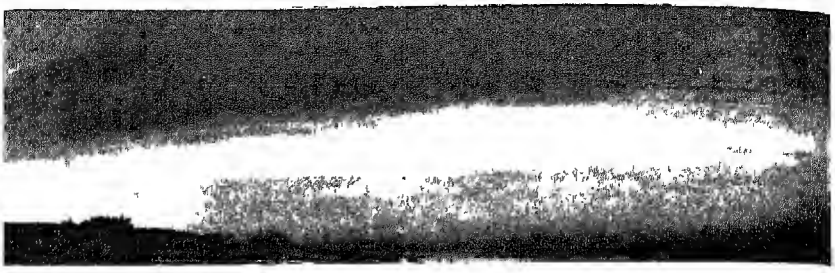


Fig. 47. *A warm front approaching from the west. It shows a well-defined edge of cirro-stratus, thickening to alto-stratus on the horizon. This cloud is usually preceded by cirrus, a portion of which can be seen in the top left corner.*

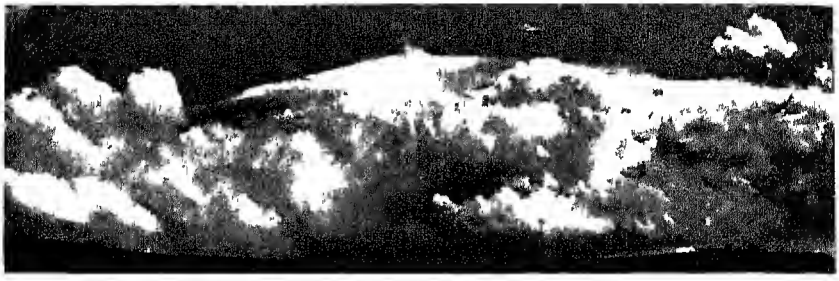


Fig. 48. *The cold front of a depression which has just passed over and is receding eastwards. Note the mixture of large cumulus masses and stratified cloud.*

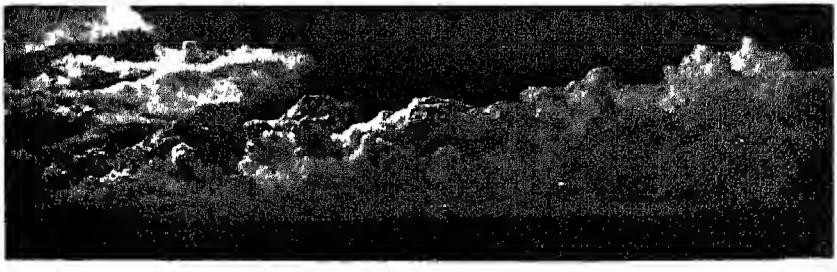


Fig. 49. *A secondary cold front approaching from the west. A "storm collar" appears to be forming low down in the left centre of the panorama.*

Out in front of the storm collar, however, there is usually a large body of smoothly rising clear air where perfectly comfortable soaring can be done.

A less active and more localised form of cold front shows as a line of ragged projections below a dark cloud mass, connected with it and rising into it; good lift, easily negotiable, has been found there.

Over the sea, a cold front can stretch for hundreds of miles in a straight line. But over the land the line of advance is apt to get bent, and mountains can break it up badly by holding up the cold air and diverting it along valleys. In these conditions the soaring area is not so easily recognisable, or a pilot using it may suddenly find fresh cloud forming round him.

Actually, the mechanical lifting of warm air by cold is not fast enough to account for either the good lift or the cumulonimbus, and some additional cause must be sought for. A likely explanation is that the cold front is less well defined at a great height; the cold and warm air infiltrate into each other, so that some of the polar air gets ahead at a high level and unstabilises the air below. Certainly the "anvil" clouds often project forwards above the soaring area. Further, just as stable air squashed from above becomes more stable, if squashed from the side (as tropical air before a cold front) it becomes less stable, and conditional instability may arise where it did not exist before.

A cold front should, in theory, set up a wave motion, resembling standing waves, in the raised warm air above and behind it, rather like the "bore" of a river on a large scale.

Since at the warm front the warm air moves faster than the cold and has to climb up over it, and at the cold front the cold air moves faster than the warm and has to push underneath it, the cold front eventually catches up the warm front and the warm sector is lifted off the ground; this happens first at the centre of the depression and then farther and farther south. The two bodies of polar air, originally preceding and following the warm sector, now meet along a line called an *occluded front* or *occlusion*, and the depression is said to have been *occluded*.

What happens along this front depends upon which side of it is the colder, that preceding or following (east or west of) the occlusion. In Western Europe, the preceding air has usually spent some time over the land In winter, therefore, it is likely to be the colder, so that the occlusion resembles a warm front

Fig. 50. The ragged under-side of a cold front. Scraps of cloud can be seen forming below it and rushing up to join the main cloud mass, showing the presence of a powerful up-current.

and is called a *warm occlusion*; in summer the preceding air is probably warmer, so a *cold occlusion* results and, as it resembles a cold front, may provide lift for sailplanes. The lowest part of the lifted warm sector, containing the thickest cloud, continues to give forth rain for a time; the occlusion at ground level is preceded by it if warm, and followed by it if cold.

After the passage of an occlusion, the following polar air is at first overlaid by the high cloud of the lifted warm sector, which spreads backwards over it more and more as the occlusion gets older; this blots out the sun and discourages convection. But as soon as this high cloud has cleared off, convection starts up in earnest, and may produce a long line of cumulo-nimbus resembling a cold front, parallel to the occluded front and following it after an interval. This is one form of *secondary cold front*.

Sometimes secondary cold fronts follow each other at regular intervals of an hour or more in the rear of a depression. The condition for their existence is that a fast polar air stream shall bring continually colder air from the arctic. Since the wind blows faster up above than on the ground, especially if strong, colder and yet colder air arrives sooner at a height than at ground level, and extreme instability results.

These secondary cold fronts extend laterally for hundreds of

miles; they are often heralded by a "storm collar," and resemble a typical cold front except that they bring no permanent change of wind. Each one is likely to provide a soaring area in the clear air just in front of it. A wide belt of down-current separates one secondary front from the next; it is rarely possible for a sailplane to cross it.

Short secondary cold fronts can also arise in front of isolated cumulo-nimbus clouds, the cold air having descended from inside the cloud. A localised "storm collar" is the most reliable sign of their presence.

All the sequences of weather so far described are found on the equatorial side of the centre of low pressure. In the northern hemisphere this is, of course, the south side, and it will be observed that, as the depression passes by, the wind gradually changes so as to blow from farther to the right. This change is called *veering*. Then if, after one depression has gone by, another approaches, the wind moves to the left again, back to where it was before, and this is called *backing*; it is a sign that the weather will deteriorate once more.

It is not uncommon, when a whole series of depressions goes by, for a gradual veering to be superimposed on the alternate veering and backing. For instance, if the first of the series causes the wind to veer from S.E. to S.W., it backs to S. for the next, which in turn causes it to veer to W., and so on. The low pressure region may end up over Scandinavia, causing a wind shift between N.W. and N.E. as depressions move down the North Sea.

Often each depression of a series forms farther south than the one before, sometimes a new low-pressure centre arising at the southern tip of the occluded front belonging to the previous one, and developing into a so-called "secondary depression." The "polar front" thus advances farther towards the equator, and the time comes when a depression centre, moving from west to east, passes *south* of the observer. Then the wind, instead of veering with its passage, *backs* through E., N.E. and N. to N.W. The north side of a depression is rainy without frontal phenomena. When the rain clears, polar maritime air usually takes its place, with good thermals and cumulus.

As a depression gets older, the high cloud sheets are increasingly divided into parallel bands. By the time it has reached

the advanced age of a week or more, the various fronts have become feeble and distorted and it ends its life as a large-scale whirl of wind.

"Shallow" depressions (without much fall of pressure) are characterised by much alto-cumulus. They are of two kinds: the "weak," whose approach brings a gradual increase and thickening of an alto-cumulus sheet; and the "thundery," in which there is little wind and a so-called "chaotic sky" of patches of alto-cumulus at several levels, often with cirrus streamers hanging below. The cause of the conditional instability is a slow raising of the air due to heating over a vast region, the effect being the opposite to that of subsidence. The thunderstorms, when they come, are apt to be unconnected with ground thermals and difficult to reach by sailplane from a low launch.

Sometimes a depression slows up and becomes stationary, and so does its rainy region; or it may wander off slowly in any direction. Not infrequently one may be formed entirely in polar air. In fact, the vagaries of depressions are infinite, though most of them follow a fairly typical course.

This variation from the typical is common in all meteorological phenomena. The sailplane pilot must continually bear it in mind, and never be deterred by mere theory from looking for lift in the most unexpected situations.

Chapter 6

CROSS COUNTRY FLYING

The Aircraft

The would-be cross-country pilot should first thoroughly appreciate the necessary requirements of a suitable sailplane. These are: first, performance, and second, stability. As regards performance, modern sailplanes easily attain the minimum performance required for ordinary cross-country flying in the summer months in Great Britain.

On any reasonably unstable day between mid-March and mid-October up-currents of the order of 5 ft. per sec. and upwards may be expected. Hence any machine with a sinking-speed of 3 ft. per sec. or better can be piloted across country, the distance covered depending on the weather conditions, the skill of the pilot and the machine's "penetration" as defined on page 246.

Numerous cross-country flights exceeding the Silver "C" requirement of 50 kms. have been carried out on strutted machines of the "Grunau Baby" type, with a sinking-speed around 3 ft. per sec. and a maximum gliding angle of 1 in 17. But naturally the best result can be expected with the highest performers. Sailplanes of the normal type available reach figures approaching a gliding angle of 1 in 29 with a sinking-speed of 2 ft. per sec.

A much less widely appreciated requirement in all sailplanes, particularly for advanced flying, is good handling qualities. This term covers lightness and balance of controls and stability.

Controls are balanced if the same amount of force has apparently to be applied to each of them in the air to produce the same degree of movement. I say "apparently" because, of course, the leg muscles are of a different order of power to those of the arm, so that one degree of effort on the rudder pedals will give the same sensation of resistance as a different one on the stick. Thus a stick force of say 3 lbs. will feel the same as a different force, as measured by a spring balance on the rudder. One instinctively realises this by talking of the "feel" of the controls. As the mechanics of aileron control involve more friction than those of rudder or elevator, the most

common defect in the balance of sailplane controls is to find the ailerons much stiffer in operation than the other two controls. This can be minimised by aerodynamic means or by such mechanical refinements as the fitting of self-aligning ball-bearings, particularly on aileron controls.

Coming to stability, the following three definitions are fundamental:

Positive stability is the quality in a machine of returning to "straight and level" normal flight if the controls are left free when the machine is in any normal attitude.

Neutral stability is the quality of remaining in a given attitude if the controls are left free in that attitude.

A *negatively stable* machine will tend to exaggerate a given attitude if the controls are left free.

Thus, in a straight dive, a machine which is positively stable in pitch—if left with controls free—will pull up its nose until it regains level straight flight; a neutrally stable machine will keep in the dive at the same angle; a negatively stable machine will go on diving at a steeper and steeper angle until it is on its back.

In a turn, the negatively stable machine will tend all the time to increase the angle of bank and yaw and have to be held from the tendency to dive into the ground. After a certain point full opposite aileron and rudder will be insufficient to hold the turn, and the pilot will be forced to dive out of it.

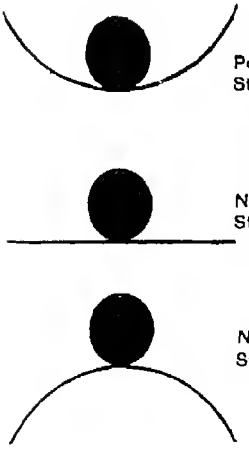


Diagram 12. *Three billiard balls.*

(a) In a cup is positively stable, and if moved it will tend to return to its original position.

(b) On a flat (frictionless) table is neutrally stable: if pushed in any direction it will continue in a straight line at a steady speed.

(c) On an inverted cup, if moved, will fall away from its original position with constantly increasing velocity.

Fig. 51. *Minimoa approaching to land at Inkpen.*

The purchaser of a machine should therefore make sure in a test flight, by trying the machine out with hands and feet off the controls in straight flight and in turns, climb and dives, which class it comes into. Remember that a machine may be stable in one dimension and unstable in another.

For cross-country flying, neutral stability gives a delightful feeling of responsive control, though a positively stable machine is probably slightly easier for the inexperienced pilot.

For altitude flying in clouds, positive stability is almost an essential for all but the most accomplished pilots.

A negatively stable machine is an unnecessary hazard in any circumstances.

In a machine with well-balanced controls and with good stability, a turn should be able to be held with the minimum of opposite aileron and rudder, and with no, or only a slight, backward pressure of the stick.

Aerodynamicists will realize that the above is an over-simplification of a rather complex subject, and does not take into account the definitions of static and aerodynamic stability.

However, this chapter being intended for ordinary pilots, the subject has been deliberately presented in a way which it is hoped will be enlightening to the ordinary user.

It is very desirable that, just as no aeroplane would be considered safe which would not trim to fly hands off, so no sailplane should be considered suitable which cannot be trimmed to fly hands off "straight and level" for any weight of pilot.

Lastly, the stall, both in straight flight and in steep turns, should be gentle and should give plenty of warning of its arrival, and recovery from the spin easy and normal.

The Instruments

Sailplane instruments have already been described elsewhere in this volume. For cross-country work, the essentials are an air-speed indicator, compass, altimeter and, most important of all, a good variometer (rate-of-climb indicator). A recording barograph is necessary to record any official flights; and a turn-and-bank indicator is useful as a check on accurate flying and as a precaution in case any unexpected cloud-flying is encountered. But serious cloud-flying need not be indulged in on most cross-country flights, and should not be essayed until proper instructions has been taken. A cheaper alternative for ordinary work, but *not* for cloud-flying, is a bubble in the banking plane. Many pilots will find by reference to the bank needle of the turn indicator, or to the bubble, that they are incorrectly banking their turns, and so constantly slipping slightly inwards or outwards with a consequent loss of efficiency.

A parachute is also a necessary precaution for any advanced soaring.

Clothes

As for clothes, the sailplane pilot, without any outside source of additional warmth, has to find some protective wear which does not take up much room and yet is readily adjustable to temperatures which on a single flight may vary up and down rapidly between 85° F. and freezing level, or even below.

By far the most successful garment I have found is a pair of wind-proof overalls with zip-fasteners on the legs and sleeves and in front. With a sweater underneath, and a pair of zip-fastened fur-lined soft leather flying boots, one has a kind of adjustable radiator gear in the shape of the various zips.

The Plan

With these fundamental preliminaries disposed of, let us imagine the pilot preparing for a cross-country flight.

He has already weighed up the weather in the general sense, and concluded that conditions are going to be good enough for the attempt.

Now he has to plan his flight in detail. The preliminary planning of a flight is almost more important than the flight itself. Not that any plan comes off exactly more than once in a hundred times. But by producing a plan the pilot sets himself a standard by which he can criticize himself afterwards, learn his mistakes, and so slowly improve his technique.

After every flight, a pilot should conduct a private post-mortem to find out where his plan went wrong, and why. His next plan should then allow for previous errors.

The first point to be decided is whether a straightforward cross-country flight, attempting only maximum distance, is to be attempted, or an out-and-return flight round a pre-decided point, or a goal flight to a declared destination.

Fig. 52. *Hjordis. The first all-British high-performance sailplane at the start of a winch launch. Note the rubber shock absorber in the cable.*

This decision requires a detailed assessment of the expected weather. The meteorology of sailflying has been covered elsewhere in this volume, but only by trial and error, and accumulated experience, can a pilot expect to improve his practical weather interpretation.

Personal contact with a sympathetic meteorological officer before each flight is by far the best method, but if this proves impossible, a telephone conversation is second best. Alternatively, each club might detail one or more of its most weather-wise pilots to contact the area meteorological office, and write out a daily interpretation of the weather situation for the club notice-board.

The greatest distance on an unstable day can clearly ordinarily be attained with a flight directly down-wind, but an additional complication in this country is that down-wind flights usually bring one fairly soon to the coast; so that very often it is necessary to follow a dog-leg course to get round some bay or arm of the sea.

The degree by which a cross-wind course can be flown clearly varies with the strength of the wind and the "penetration" of the particular machine. On a calm day any course can be selected, the only consideration being the geography of the country to be crossed and the prevailing weather situation from the up-current point of view.

A goal-flight attempt involves course-finding in addition to other cross-country technique. It is therefore a good tip *always* to declare a goal before a cross-country flight; if the goal is reached too easily the pilot can always carry on for maximum distance, and the fact that his plan proved under-ambitious will prove instructive. One of the differences between the beginner and the experienced cross-country pilot is that the latter always knows where he is.

On a day of light wind, any goal within a down-wind sector of up to 135° may be practicable, whereas with upper winds of the order of 35–60 m.p.h. a down-wind sector of as little as 10° may cover all attainable goals. In planning these flights, it is important to remember that it is the upper-wind direction and strength (that of the wind above, say, 1,000 ft.), which must be considered, and this frequently varies very considerably from surface wind direction and strength.

Apart from weather considerations, the type of country to

be crossed has a considerable bearing on the best route to follow.

In Poland before the war a "thermal map" of the country had been prepared showing the different areas where up-currents were to be expected above or below the average. In this country no similar map as yet exists, though the part author of this volume has for some years been collecting the data necessary for its compilation.

Generally speaking, however, exceptionally wet or marshy areas or pockets are bad for up-currents. Blackmore Vale, in Dorset, appears to be one such example. Dry, chalky limestone, or sandy areas, such as Salisbury Plain, may be expected to be particularly suitable for up-currents.

Down-wind of any industrial town the smoke-trail will on many days cut the sun off from the ground and so produce a band of dead air which in some conditions may extend up to 100 miles down-wind of the source.

Many people believe that mountainous country should prove good, but my experience is that really broken country such as in the Pennines chops the air about too much, so that vertical currents are frequently broken and hard to assess from a distance. This is more the case in moderate or strong winds, on calm- or light-wind days such country is probably better than average.

Before the war, however, little aero-towing had been done, so that on such days little cross-country flying had been carried out, and data regarding up-current conditions on calm- or light-wind days is still rather scanty. The writer, however, carried out one flight across the Pennines in 1938, from Kirbymoorside to Lancaster, from an aero-tow on a light-wind day. Up-currents were good but not surprisingly so over the mountain chain, but the goal of Blackpool was not reached because the Lancashire plain was completely devoid of lift, and subsequent observations tend to show that this area is probably one of the most anti-thermal in the country.

It is safe to say that after 350 hours' sailflying it is still the exception rather than the rule to carry out a flight in which something is not learnt. For instance, in a certain wind direction on an unstable day, a particular patch of country may produce satisfactory up-currents, whilst the same patch in any other wind may easily be one to avoid.

Thermal conditions must necessarily be far more complex in a small highly-industrialised island country dotted with towns and without any large homogeneous geological areas than over a continental landmass.

As for out-and-return flights, a point worth noting is the extreme difficulty of arranging an observer to confirm the turning point. Even if this is pre-declared, no observer can well lie on his back for hours on the look-out for a noiseless, and probably almost invisible, high-up machine to circle him.

The Technique

The basic evolution of thermal circling has been described elsewhere in this volume, and possible variations to meet the numberless variations of incident which can occur in advanced sailflying are too numerous to cover exhaustively. I will therefore confine myself to a few points which should indicate the general scope of the subject.

Finding Up-currents

Having reached the top of his first thermal, the cross-country pilot's immediate task is naturally to decide where he is most likely to find his next piece of lift.

In this country most cross-country flights are carried out under cumulus conditions, and experience will help the pilot to sort out the looks of an active or a dead cumulus.

The up-current forming a cumulus naturally slants up to it leaning in the down-wind direction. The pilot will probably, get the clearest idea of the sort of track followed by a thermal by closely observing smoke columns which, on unstable days, can frequently be observed all the way from the ground up to the cumulus cloud which their source is creating.

Watching such a column of smoke, one can see how it wavers about on its upward path, and this makes it surprisingly difficult to locate an up-current from the position of its cloud-cap unless one is still high enough to be within about 1,000 ft. of cloud base.

However, a prospective thermal should of course be approached from behind—*i.e.* from down-wind, and if the up-current is missed, an indication that it is not far away is provided if a fairly strong down-current is met instead, every thermal being the strong core of a weaker surrounding belt of

descending air. Unfortunately, when one meets such a down-current there is no indication of which way to turn to find the rising centre of the thermal, and one is usually losing height so fast that there is not much time for much trial and error work. The best method is to go on, hoping to find the up-current straight ahead, and if one flies back into smooth air, decide rapidly whether enough height remains to get to a more likely area or whether to turn back and try out the thermal on another track.

Any tendency for a wing to lift indicates a likelihood that the up-current is on that side, since a sailplane automatically tries to turn out of any rising current which is not met head on.

On a cross-country flight speed is the essence of success, and whilst in a thermal the pilot must continue trying to find the most active area. Generally speaking, on any given day the up-currents will be of about the same strength, so if one manages to find an up-current giving a maximum climb of, say, 6 ft./sec., one should continue manœuvring in all subsequent up-currents until one attains the same rate of climb.

Whilst circling in an up-current, it will generally be noticed that the machine is climbing better in one sector of the circle than in the rest. To identify this sector with sufficient precision it is clearly necessary to have a variometer with the minimum lag. The pilot should then try to edge his machine over into the

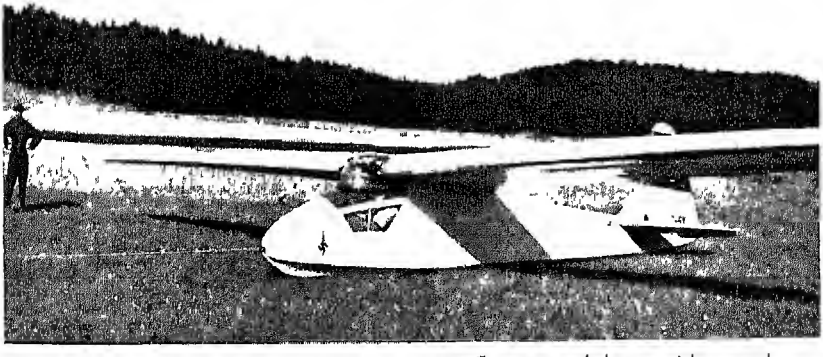


Fig. 53. *The Mu. 13: a high-performance German sailplane, with a steel tube fuselage, which won 5th prize at the 1937 International Competition at the Wasserkuppe.*

more active part of the up-current either by making his circles into ovals or else (a more kill-or-cure method) by doing a figure-8 at the correct point.

When too low to get much indication from the clouds as to the possible location of the next up-current, the pilot must perforce transfer his attention to the ground.

The roofs of a town, large areas of tarmac, dry stubblefields

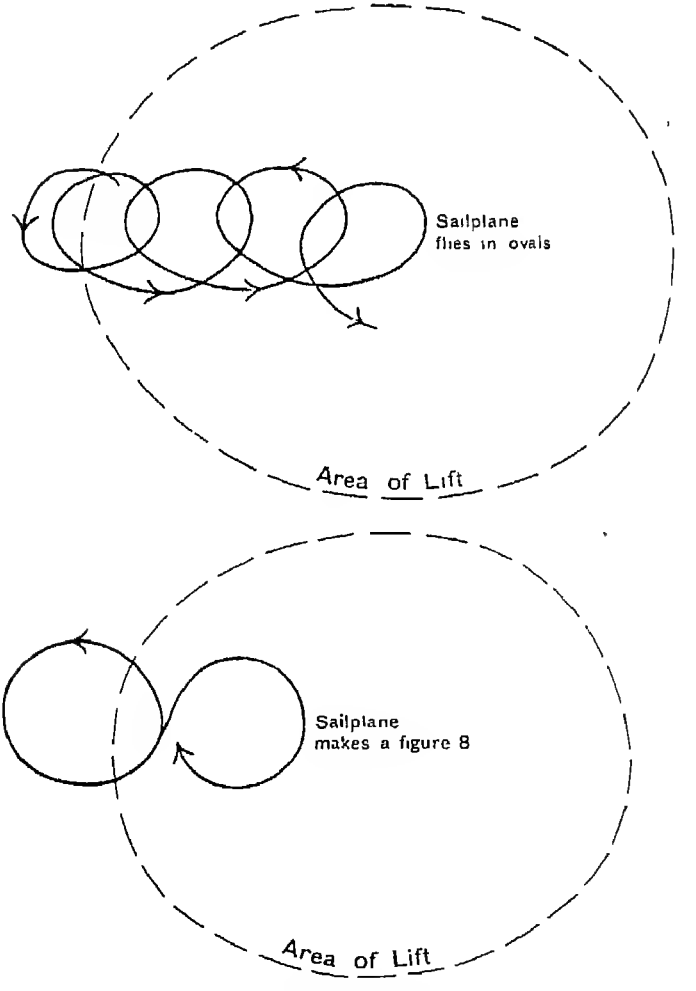


Diagram 13. *Two methods of edging into the heart of a thermal.*

or areas of chalk, sand, or limestone (which is not covered by surface clay) are clearly good hunting country on a sunny day. Sometimes a small soaring slope can be found to keep one in the air until another thermal comes to the rescue. Near the coastline there is frequently an area of rising air where the inshore sea-breeze meets the prevailing wind.

Optimum Flying Speeds

The next point is to decide what is the correct speed at which to fly at different stages of a cross-country flight. Unfortunately, the answer to this is bound up with the polar curve of the sailplane concerned. This is the graph showing rates of sink at different flying speeds. It is a document which is very difficult to produce. Only in Germany, and even there only on a few selected sailplanes, have actual polar curves been obtained. However, a theoretical curve can fairly easily be plotted by the designer, and providing he does not make it too wildly optimistic, is probably sufficiently near the mark for most practical purposes.

The way to use this curve for the kind of purpose in view is described in the following article of mine published in the *Sailplane* for March/April, 1940:

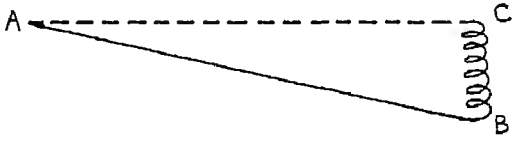


Diagram 14

"The average man, like the square root of minau one, does not exist, yet useful conclusions may be drawn by considering them. So let us consider the average cross-country flight.

"This may be subdivided into a number of units of the following type:

"Starting from optimum height A, the sailplane descends to B, where it meets the next thermal, in which it circles up to C. The effect of any wind is to slant BC from the vertical, but this may be ignored for the present purposes.

"Since the duration of each flight is limited by the declining sun, the pilot who will travel farthest on a given day is he who can get from A to C in the shortest possible time.

"The time taken from A to B is, of course, $\frac{AB}{v}$, where v = the speed of the sailplane. The time from B to C is $\frac{BC}{k}$, where k = the average strength of the thermals on a given day, or rather the average rate of climb registered by the variometer on that day. This may be taken as constant on a given day; if one works the first thermal up to, say, 6 ft./sec., one may expect to find the next thermal to be about this strength. The distance BC varies with v, since the faster the pilot flies from A to B the more height he will lose. What the pilot has to do, therefore, is so to manage v as to reduce to a minimum the time T, which equals $\frac{AB}{v} + \frac{BC}{k}$.

"It does not affect the value of v if the thermals are not spaced equidistantly so long as they are not so far apart as to bring the sailplane low enough to lose the region of average up-current strengths. If point B comes below, say, 1,000 or 1,500 ft., the system falls down: it is only valid on good days.

"As we have said, in the above equation the one term which is in the control of the pilot is v, the velocity at which he flies from A to B. From B to C, of course, he flies at the minimum sinking speed rate, which is constant. Up to now, pilots have simply had a general notion that it was a good thing to crowd on a bit of speed between thermals. Clearly, however, v is capable of reasonably exact determination, and *varies from day to day.*

"If at speed v the sinking speed is s, then $BC = \frac{s \cdot AB}{v}$, so $\frac{AB}{v} + \frac{s \cdot AB}{vk}$. The average *speed* at which the sailplane will cover the ground throughout the flight is $\frac{AC}{T}$. As above, $T = \frac{AB}{v} + \frac{s \cdot AB}{vk} = \frac{k \cdot AB + s \cdot AB}{vk}$. So the average speed S equals $\frac{AC \cdot vk}{AB\,(k+s)}$. But since the angle CAB is small, $\frac{AC}{AB}$ is approximately 1, and may be ignored, so $S = \frac{vk}{k+s}$.

"Now we get out the performance curve of the sailplane and work out its speed table. Let us take a medium to good summer's day, and a well-known type of advanced sailplane: k = 6·6 ft. per sec. Flying at the minimum sinking speed, 38·5 m.p.h., S comes out at 29 m.p.h. approximately. At 52 m.p.h. S = 35 m.p.h. It will be seen how substantial is the gain to be attained by working to this table. The actual table for the machine in question is as follows:

k	v	S
metres/sec.	m.p.h.	m.p.h.
0·0	44	—
0·5		17
1·0	52	27
1·5	55	32
2·0	58	36
2·5	62	39
3·0	66	42

"S, of course, represents the average speed on a calm day, and on days with following winds really remarkable average ground-speeds appear to be attainable."

The machine referred to in the above is the Minimoa. The polar curve for this machine was taken by D. F. S. Darmstadt in 1937 (*see* diagram 15).

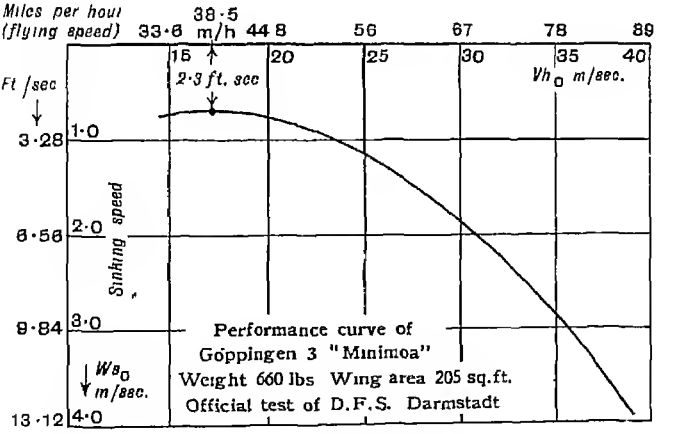


Diagram 15

Coming Home

There is no other way of determining how good a pilot one is than in competitions, when a number of pilots simultaneously attack the same set of conditions.

The best method of retrieving is particularly important in competition work, where day after day a pilot sets off across country and has to get home again in time to get enough sleep to put him on the top line for the next day's flying.

In fact, in competition work, the three factors: machine, pilot and retrieving team, are all of equal importance.

When the pilot declares his goal for the day, it is clear that, unless he has made a really serious miscalculation, his general line of flight will be in approximately that direction. Immediately his team see that he has got properly away on a thermal, they set off for the declared goal. Both pilot and team have the telephone number of the club from which the flight is being made.

Every hour the retrieving team phone back to the club for news; if none has come through they carry on. Immediately the pilot lands, he gets to the nearest phone and rings back to the club giving his whereabouts. His team will then, of course, get this information when next they ring through, and since the average speed of a car and trailer is of the same order as that of a sailplane on most cross-country flights, the retrieving team is likely to be quite near its machine. Competition Retrieving has been described as a large-scale Egg-and-Spoon race. In a democratic country it requires a degree of selfless devotion which is priceless.

The accompanying map showing the work done by my own private retrieving team in one month (April 1938) will show what I mean.

A Flight

In selecting a description of a flight to illustrate the various main points outlined in this chapter, the difficulty is to find one in which the author has followed the method of (*a*) telling us his pre-flight plan (what he meant to do), (*b*) describing the actual flight (what actually happened), and (*c*) giving the lessons subsequently learned (the reasons deduced for the discrepancies, if any, between (*a*) and (*b*)).

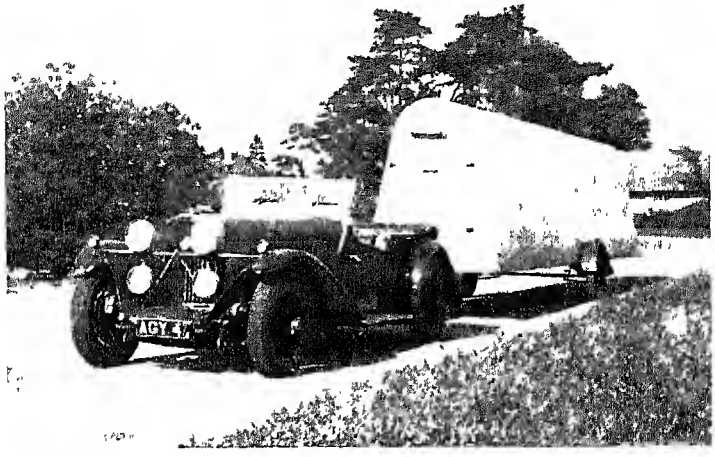
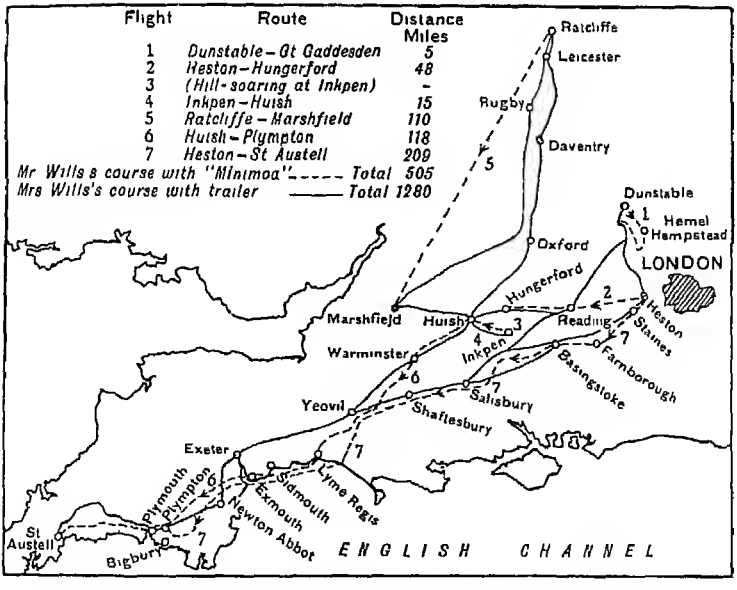


Fig. 54. *Towing-car and neat trailer which houses the 55-ft. 9-in. span Minimoa.*



Routes of first seven flights of "Minimoa" (pilot: P.A. Wills) during week-ends in April, 1938

Diagram 16

The following description by K. Lingford of a flight in a Kirby Kite during the 1937 competitions exemplifies the classical method:

"*Eighty Miles to Easington*

" 'Doncaster will do for to-day,' I replied, when asked to declare a goal on the Saturday of the National Competitions. On the two preceding days that madness which seizes a sailplane pilot when he sees a cumulus cloud riding down a westerly wind had led me to declare for distant goals. These had proved to be beyond the reach of my inexperienced fumblings, and I decided on caution for once.

"Caution was also the policy for the first half-hour in the Kite over Bradwell Edge, when, profiting from my lesson of the previous day (a premature departure which resulted in an ignominious descent at Sheffield), I several times left thermals to make a safe return to the hill.

"At last a good one carried us up to cloud base at 3,000 feet and we were off. (This is not an editorial 'we'; I always look upon a flight as a joint effort by the sailplane and the pilot, and who dare say that a sailplane is an inanimate object?)

"A race to a better-looking cloud was won by the Cambridge II, which promptly disappeared inside it, and I retired in some haste to my original cloud, under which I stayed until it broke up over Sheffield. Here, thermals could be both seen and smelled, and cloud base was soon reached again. We passed Peter Davis in his Scud travelling at speed in the opposite direction and at the same height, while a long way below another Kite was nosing around after lift.

A promising storm cloud was responsible for some sticky moments when it provided beautiful mammatus formations and a steady down-current of 20 feet per second. At last the green ball (indication of rising air on variometer—ED.) staggered upwards, and we with it, at six inches rise towards a little puff of cloud forming far below the large mass. So emotional had the last few minutes been, that when I looked at the ground again Finningley Aerodrome was almost immediately below, with Doncaster just visible a few miles to the north. I estimated that with the height I had, and nothing too frightful in the way

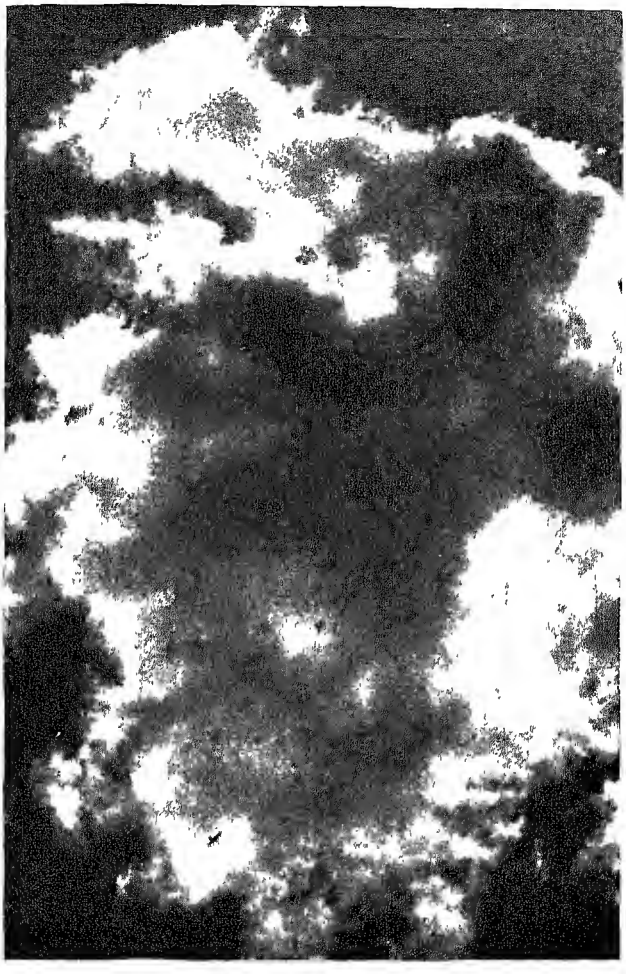
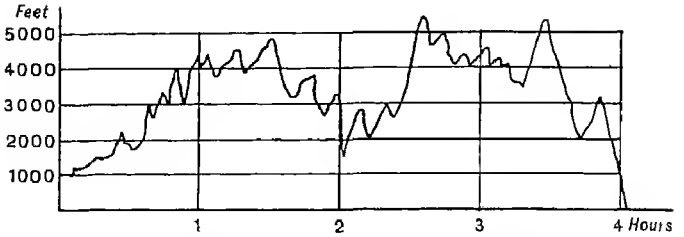


Fig. 55. *Twa sailplanes circling under the base of a cumulus side, seen from directly below.*

of down-currents, it was comfortably within range. Actually. we encountered a small thermal on the way, and arrived with 1,500 feet to spare.

Once at my goal it seemed a pity to land after so short a time in the air. Surely, I thought, the roofs of Doncaster will be sending up thermals. Almost at once I found two, each taking



Copy of Barograph Record. K. Lingford in "Kirby Kite"
Bradwell Edge to Easington, 80 miles. Sept. 4th. 1937

Diagram 17

me up about 500 feet, after which I worked back into wind for another. Then came the dream-thermal, large, smooth, and about ten feet per second all the way from 1,000 feet to cloud base at 4,600 feet (above start). Cumuli were popping up all around, and a long dark shadow stretching away to the east made a thirty-mile goal flight seem merely silly.

It was almost impossible to go wrong now, though plenty of circling was necessary once the first short street was left behind. Landmarks dropped behind slowly; the field where I had landed two days before, at Luddington, but viewed this time from 5,000 feet; the Trent, the Humber, Hull, then that thin blue line which means journey's end for the sailplane pilot. As I flew across the Humber in the dead air 5,000 feet up, I managed to get a map open and make some rough calculations. I was now within gliding distance of any point on Spurn Head, but to get any farther I must make twenty miles northwards to Flamborough Head. This, apart from purely personal reasons of cold and hunger, was going to be difficult, as activity was obviously decreasing, and the wind was still fairly strong. Another look at the map showed a bulge just north of Spurn Head itself which seemed to be the farthest point from Camphill, and a short way inland was a village, h. and c., and beer.

"We were over the coast just south of Withernsea, when a thermal presented itself. A psychologist will doubtless point out that circling a sailplane is a reflex action stimulated by the sight of a rising green ball. Anyway, we gained a thousand quite unnecessary feet, and set off southwards a mile or two out to sea 'just to see what it was like.' Very pleasant it was, and all too soon there was the bulge, and the village.

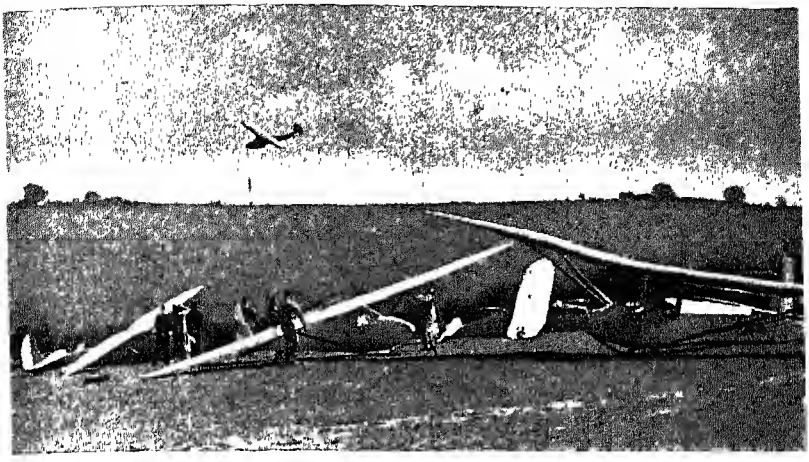


Fig. 56. *Kirby Kite approaching to land during soaring meeting at Dunstable Downs.*

"A brief survey of possible landing fields (the tide was too far in for a beach landing), a sudden surprised upturning of faces on the beach, a scrape in over the low cliff to come to rest a few yards from the edge, and we had landed near Easington, eighty miles from Camphill, having taken four hours over the journey.

"Hospitality of the most satisfying kind was forthcoming, and greatly appreciated, while that most unenviable of jobs, retrieving, was very nobly undertaken by John Simpson.

"The lesson learned from this trip seems to be that England is so small that, given a good day, a sailplane of only moderate speed range can reach the coast from most soaring sites without much difficulty. So if lift is plentiful, don't be lazy; navigate, whether you are making for a goal or not. If I had got my map out at Doncaster instead of at Hull, I should have turned northwards and *might* have made Flamborough Head."

Chapter 7

ALTITUDE FLYING

To the Heights

ALTITUDE flying to sailplane pilots is what big-game hunting is to the sportsman. It requires more skill and a higher degree of pilotage than any other branch of sailflying. It involves a slight spice of risk and—alas—more expensive equipment and training. It opens a new world of experience.

Blind flying in unstable cloud in a sailplane is as different from normal blind flying in a powered aircraft as cheese from chalk. The powered aircraft usually progresses in a straight line—frequently on an automatic pilot—and mostly in stable cloud. The sailplane is almost invariably in unstable clouds in which the pilot is carrying out circles, figure-eights and so forth, on comparatively simple instruments only.

Unfortunately, at the date of writing, remarkably little serious altitude flying has been undertaken in this country, and still less has been recorded. The reason for this is that firstly the expense of a suitable machine, with instruments and parachute, and of the necessary training, put serious cloud-flying beyond the reach of most pre-war amateur pilots, and secondly, that before the war few suitable machines for the purpose were available.

However, it is extremely probable that in the immediate post-war years large numbers of experienced Service pilots will be taking up gliding, and also new designs of British sailplanes now under way will provide a supply of suitable aircraft, so that much altitude flying lies ahead, if only Government regulations regarding cloud-flying do not hamstring the art.

The Machine

As stated in the previous chapter, the prime requirement in a machine for cloud flying is positive stability. Performance is quite secondary, since up-currents in unstable cloud are frequently very powerful. In a medium-sized cumulo-nimbus in this country up-currents of the order of 20–40 ft./sec., are the order of the day. In tropical storms the size of hailstones which fairly often emerge from storm-clouds make it possible to estimate the presence of currents as strong as 200 m.p.h. in the

vertical plane. These latter are, of course, better observed from the outside only. Parachutists have been reported to be kept bobbing up and down inside cumulo-nimbus clouds for periods of up to an hour. Clearly, therefore, the finest shades of performance are not required for cloud-flying sailplanes.

A second very desirable feature in a cloud-worthy machine is airbrakes, designed when applied to limit the speed of the aircraft in a dive to a safe maximum.

As will be explained below, one of the possibilities when blind flying is a circus-turn called the High Speed Spiral Dive, in which the machine goes into a tight diving turn. Nearly all sailplanes have "wash out" on the wing tips, meaning that the tips are twisted to slightly less an angle of incidence than the rest of the wing.

This means that when approaching the stall, the inner part of the wings stalls before the outer, so that the pilot is still left with aileron control; such a quality is clearly desirable in a machine which for much of its flying life is proceeding at speeds only a few miles an hour above the stall.

But it also means that in a steep dive after a certain point there is a down-load on the wing tip, whilst the centre portion is still lifting, and further in inverted flight the condition is easily reached when the inner part is taking no load and the entire weight of the machine is hanging on the tips. In either condition wing-tips have been known to break off. This is why very few sailplanes are stressed for *unlimited* aerobatics, though nearly all are, of course, perfectly satisfactory in normal aerobatics.

As a safety precaution, air-brakes are now fitted to many machines. An examination of diagram 36 on page 264 will show the differences between air-brakes and lift-spoilers. The latter, by spoiling the lift over a part of each wing, put up the gliding angle of a machine and so make approaches into small fields on high-efficiency machines easy. Air-brakes have the same effect, but the additional advantage of putting up the drag and so a strong limiting effect on the speed of the machine in a steep dive.

A further advantage of air-brakes is that additional drag has the aerodynamic effect of increasing the positive stability of the machine in pitch, so that if the stick is left free when they are applied the machine will gently pull itself out of the dive so long as the pilot keeps the turn needle of his turn-and-bank indicator central by use of the rudder.

Instruments

Apart from the instruments already described as necessary for cross-country work, the only necessary additions are (1) an artificial horizon, usually a simple bubble in a U-tube in the plane of pitch, which is useful if, as frequently happens, the A.S.I. fails during an altitude flight by icing up of the pitot tube, and (2) a carefully chosen turn-and-bank indicator.

The number of blind flying instruments available to sailplane pilots is, unfortunately, limited at the present time by consideration of cost and weight.

An automatic pilot is both too heavy and too expensive, and requires more power to drive than can be made available.

The same objections apply to existing types of artificial horizon, though undoubtedly a special instrument driven by small dry batteries is technically feasible.

The choice, therefore, confines itself to a suitable turn-and-bank indicator. This instrument should be electrically driven, since venturi drive suffers from icing risks, and nearly all big climbs in cloud involve traversing the icing layer. Fortunately, one or more excellent British-made instruments of this type are available, and will run for periods of up to twenty-four hours on dry torch batteries. The only maintenance the writer has found necessary on the instruments he has tried is a rather frequent cleaning of the commutator. However, a safety point is that if the instrument is going to fail for this reason, it won't start when switched on. If it starts successfully it can be relied on to go on running until switched off.

It should, therefore, be switched on for a trial run before each take-off, and then left off until about to enter a cloud or until needed during the flight.

The Plan

The planning of an altitude flight differs from that of a cross-country in that it is not so wide in scope. Many of the opportunities (which are comparatively rare) arrive unexpectedly when one is already in the air, though a particular branch of altitude flying, the exploration of standing waves, can be planned months or even years beforehand.

Altitude Flights in cumulo-nimbus.

The general nature of cumulo-nimbus clouds has been discussed elsewhere in this volume.

I think most of the tips I can usefully give on this subject are exemplified in the two successful flights in such clouds which are all I personally have achieved to date. The account of the first, on Minimoa on June 5th, 1938, follows:

A Climb in a Cloud—how the British Height Record was raised to 10,080 *feet.*

"High flying in sailplanes is perhaps the final development of the art of motorless flight, and requires a training and technique additional to all that the pilot has learnt before in achieving, first, duration, then thermal and distance flying. This is because above a certain height most climbs must be made flying blind in unstable clouds, and it is unfortunate that blind-flying training, which is done in aeroplanes, as well as the special instruments and parachute necessary to reduce the hazards inseparable from the rough conditions likely to be encountered, are expensive. This is the reason why so few high flights have hitherto been made in this country.

"The main difficulty of flying blind is that the pilot is subject to attacks of extreme vertigo, brought on either by very rough conditions or, in the case of sailplane pilots, by the need to fly blind in constant circles in order to remain within the areas of rising air which are found inside the right kinds of clouds. The uninitiated may easily get a very exact idea of this difficulty by trying the old parlour joke with a walking stick. Plant this on the floor, clasp the hands on the crook, then bend down and put your forehead on your hands, so that you are gazing at the floor. In this position shuffle five or six times round the stick, keeping its point stationary on the floor. Now stand upright, drop the stick, and walk in a straight line across the room. The sensations you feel while doing this are precisely those experienced by the blind-flying pilot after doing a spin, or a number of circles, in his machine.

"The pilot, however, is faced with the relatively more intricate task of controlling his machine in three dimensions, while his judgment is overshadowed by the rather nerve-wracking possibilities which can arise from failure. A specially strong machine is desirable; the strength factors of the Minimoa are much greater than those of a fighter aeroplane. To assist him the pilot has certain instruments, and he must learn to obey these while his senses are peremptorily telling him to do the very reverse;

and fortunately, after a few lessons under a hood in a two-seater aeroplane, one does in fact learn to divorce one's actions from one's instincts, though this partial immunity is temporary and has to be renewed regularly every year, or more often if necessary. But there is a great deal to be learnt about the internal gust-structure of unstable clouds, so that flying to great heights is still something of an adventure.

"On Sunday (June 5th) I took off from the site of the London Gliding Club, on Dunstable Downs, at 3 p.m. The conditions were good, but not extremely so, and I had no idea of going for a height record. At about 4.30, however, I struck a strong up-current, and, in company with a friend in another machine, circled rapidly up to near the base of a small cloud over Luton, at about 4,500 feet. From here I could see a rather large storm-cloud building up over Leighton Buzzard, some eight miles to the west, so flew towards this. As I got nearer it became clear that there was a very active current of air ascending into it. The base looked quite flat, as is the case with nearly all active cumulus clouds, except that along the far edge there seemed to be a darker slate-grey area, denoting a greater depth of cloud-vapour above, bordered by a hanging ragged fringe which could be seen to form constantly and to be constantly ascending into the cloud above. As I approached this my rate-of-climb indicator showed increasing lift, until it moved up to a climb of 10 feet a second. I put the machine into a circle and spiralled rapidly upwards. At this point the rapid up-current of air had lifted the seemingly flat ceiling of cloud somewhat, so that I spiralled up into a kind of diving bell, the walls formed of blue-grey cloud, with below a reducing circle of sunlit green fields. The base of this bell sank slowly down. We approached the ceiling, and everything vanished. The time when I went into the cloud was 5.10 p.m., the height about 4,900 feet.

"Entering a big cloud in a sailplane is a very different experience from doing the same thing in an aeroplane, for in the powered craft the general noise and vibration overshadow the subtler flavours of flight. I had the feeling that we had been silently absorbed by a large and immensely powerful octupus. The rush of air over the wings and body of the machine took on a different key and became smoother and quieter. One felt as though entrapped in an envelope of sticky power. The hue of the surrounding vapour, a bluish black, was octupus-like

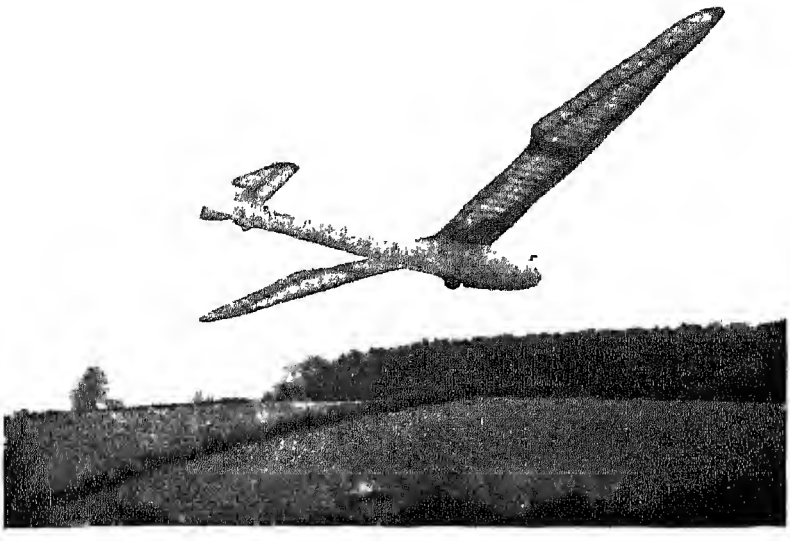


Fig. 57. *Typical field which sailplane pilot may have to use at the end of a tiring cross-country or altitude flight. Note haystack, sloping surface, and surrounding trees.*

too. This, of course, was due to the great thickness of the cloud at this point, for I subsequently discovered it was more than a mile high. It is only the shallower clouds or the fringes of the big ones which assume the friendly hues of white or light grey.

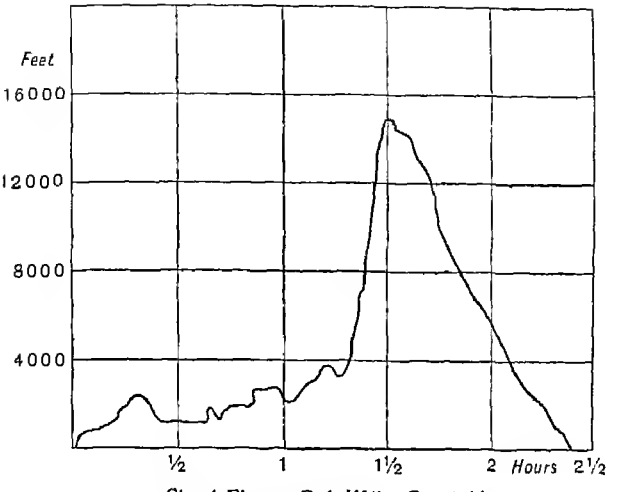
"The rate of climb now gradually increased to 15 feet a second, the only sound being the comforting buzz of the little electric motor of my turn indicator. For a while the air rose smoothly and swiftly, then we struck a rough area, and the machine started to lurch. Simultaneously, I began to feel marked vertigo, my head started to swim, and my senses to convey impressions quite different from those recorded by my instruments. Before going into the cloud I had noticed that the edge nearest to my point of entry lay to the north, so I now straightened the machine from its right-hand circles (which operation gave me the most violent, but false, impression of doing a steep left-hand climbing turn), and held her rather grimly on a northerly compass course, which about five minutes later brought us out of the towering wall of dazzling cloud into

the sunlight of 7,500 feet. I flew around, losing height, for a few minutes until the vertigo had subsided, then headed back into the cloud. My intention was to fly straight through it and out the other side, but after first negotiating a very violent down current, which shot me down at nearly 20 feet a second, I struck a smooth patch of air rising nearly as fast, so again put my machine into a circle and climbed very fast indeed.

"Now ice started to form on all protuberances, on the front of the cockpit cover and the leading edge of the wings. However, I did not meet any rain or hail, which is usual in such clouds, and I knew that Minimoas had emerged successfully from much more severe conditions after cloud flights in Germany, and was not worried. But the nervous strain is considerable for the amateur, and it was with some relief that I saw the needle of my altimeter at last top 10,000 feet, which was the height I had set myself to reach. I straightened up again and steered a southerly course. The surrounding cloud gradually lightened, then a gap appeared ahead. With joy I anticipated seeing the earth again, and the long quiet glide down and back to tea at the club-house. But I was disappointed. I came out of my cloud to find far beneath me, apparently stretching in all directions, the bulging tops of an unbroken sea of cumulus. Behind me, a mountain of white rising out of the white plain beneath, my storm-cloud towered yet another 1,500 feet up into the blue sky. It was a sight to dazzle the gods, but to me it was a pain in the neck. I wanted tea, not ambrosia.

"It was 5.45. I had been thirty-five minutes inside the cloud. As I slowly descended towards the cloudsheet beneath I searched for a gap through which I might descend without having to do further blind flying with the possibility of encountering more unwanted lift inside the clouds beneath, and at length I did in fact find a small gap through which I could see, an incredible distance below, a vista of green and brown fields and a road. I circled steeply down through this, occasionally penetrating the surrounding clouds, and emerged a short while later just to the north of Luton, my cloud having drifted about eight miles while I was inside it.

"I set the nose of the Minimoa back west for Dunstable and had a good look round. Along the leading edge of the wings, 58 feet in span, ran a three-quarter-inch ribbon of jagged ice-crystals. Similar crystals had formed on the front of my trans-



Cloud Flying. P. A. Wills, Dunstable
Climb to 14,170 ft 1 7 39

Diagram 18

parent cockpit cover and on various protuberances on the outside of the machine. In absolute silence we planed down to 4,000 feet, when a sharp crack made me jump in my seat. I looked anxiously round. Then a spark of watery light flew by, and a lump of ice, melted from the nose, flew back and hit the wing with a crack like splintering wood. Next similar sounds started from the tail, and it was quite a relief when, at about 2,000 feet, the last white fragments had gone and all was again quiet.

"The landing was at 6.15, and the height recorded on my barographs, subject to official correction, was rather over 10,000 feet."

The only additional comment I should make on the above is that subsequently I have discovered that I personally am particularly liable to vertigo in blind-flying conditions, so that this major difficulty is probably for many pilots less of a problem, though always present to a degree which must not be under-estimated.

Altitude Flights in Standing Wave Systems

The standing wave is geographically a practically stationary meteorological phenomenon. That which occurs for instance in

Cumberland, known locally as the Helm Wind, has been recorded in history for hundreds of years.

The sailplane pilot may therefore get a lot of quite definite information as to the probable whereabouts of the up-currents from local meteorologists.

Quite recently (the *Sailplane*, Dec. 1945) some very interesting and detailed data has been published by Mr. Terence Horsley on a standing wave system he has explored in aeroplanes near Dundee, in Scotland.

The general technique of tackling such up-currents is well exemplified by Mr. Noel McLean's description of his flight in a Grunau Baby in the Helm Wind on 22nd June, 1939:

11,000 *Feet in the Helm Wind.*

"The Helm Wind was blowing strongly down Hartside at mid-day on Thursday. The famous black bar of lenticular cloud was lying at about 8,000 feet along the ridge with its satellite, the lower bar of cumulus cloud, denoting the turning point of the Helm Wave, at 3,000 feet.

"I was launched in the Newcastle Gliding Club's Grunau Baby sailplane at 12.40 p.m. from the foot of the Hartside Ridge. The wind was blowing from north-east at about 25 m.p.h., and after casting off the winch cable at 600 feet, I immediately struck lift at 10 feet per second over the big field from which we were operating.

"For a few moments it was pleasant flying. But at 1,000 feet conditions became really rough. At times the aircraft was momentarily out of control, powerful gusts throwing the machine on to its wing tips. The feeling that the parachute was strapped securely to my back was a comfort!

"Suddenly, however, the turmoil died away, and then began the most remarkable period of the flight. I was apparently in smooth air, but the instruments in front of me were performing evolutions which for a time were difficult to believe.

"My variometer, which denotes the rate of the aircraft's ascent and which reads up to a lift of 20 feet per second, was off the scale. The altimeter needle was moving upwards almost with the speed of the second-hand of a watch. It became obvious that I was rising like an express lift, at a rate which could scarcely have been far short of 40 feet per second.

"The slopes of Cross Fell slid away rapidly below me; the bar of lower cumulus cloud went by. I remained over the original launching point, rising all the time in this smooth wave of air, wondering what was going to happen next.

"At 9,000 feet the lift suddenly petered out. I should have been left with the lenticular cloud, which had been lying farther out over the valley, but which had now disappeared in the extremely dry air conditions.

"Between 9,000 and 9,500 feet it was a struggle. But then suddenly the lift returned, and once again the green ball of the variometer shot off the top of the scale.

"This continued to 11,100 feet, at which height I cruised gently round for about twenty minutes.

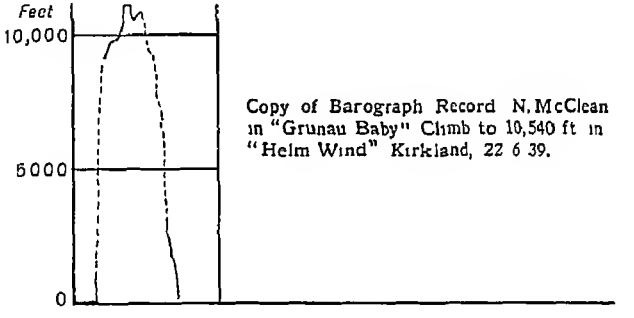


Diagram 19

"Through the openings in the clouds I could see the coast of North Wales in the south, the hills of Scotland in the north, and far away in the east through yet another gap, the green of the North Sea.

"It was extremely cold, and later I discovered that the ink on the barograph needle had frozen. Had I not been carrying a second barograph, which continued to function, there would have been no official record of the flight.

"My next problem was how to get down again through the Helm Wave. I tried diving the machine at a steep angle, but with little success. There were moments during successive dives when the instruments actually continued to register a rise. I tried a spin, but failed to hold the machine in this position. Lastly, I tried a series of steep side-slips, which at last proved

effective. By moving east over the tops of the Pennines, I got out of the main lift at 8,000 feet and managed to come in low over their crests.

"Once here it was plain sailing, for a violent down-draught carried me rapidly down the slopes of the hills to make a landing close to the point of the original take-off.

"I had been up for two hours, and in the meantime the wind velocity had increased to over 40 m.p.h. The most anxious moments were perhaps those immediately after landing, for it required a strong crew to hold the machine down until it could be got into the shelter of a wall."

The Technique

The technique of altitude flying largely confines itself to the technique of blind-flying a sailplane; and this differs in emphasis from the technique of blind-flying a powered craft.

My own introduction to the particular difficulties of blind-flying in sailplanes was in 1936 by the hard way, as the following report, published in the *Sailplane* of July of that year, shows:

On Blind-flying Blindly.

"There may be a few who are born flyers, there must be some who will achieve blind flying, but there already are several pilots now who have had blind flying suddenly thrust upon them. Since the results of this may be considerably more drastic than some of us realize, and since the subject is full of interest, it is hoped that the following notes will be useful. Always bearing in mind that the writer is no 'number 7' technical hat, but merely an enthusiastic amateur.

"Having at last a machine equipped for cloud flying, I have for some time rather nervously been nibbling at clouds. I employed the technique of circling into a cloud as near as possible to one edge, so that when and if I had had enough I would come out in quite a short time by straightening up and steering a compass course for the adjacent edge. I found that in any turbulence the best I could do was from five to ten minutes, after which one's mental resistance seems exhausted. In smooth cloud, however, it is easier, and on one occasion I circled quite happily for perhaps fifteen minutes and nearly 2,000 feet until I decided to come out on account of heavy snow.

"This experience no doubt produced over-confidence, so that on June 7th, at Bradwell Edge, after a rather abortive week's holiday, failing to glide in bitter north-easterly winds and rain, I circled into a rather amorphous and large mass of grey cloud at about 2,500 feet without locating an adjacent edge or anything else.

"It was mildly, but not excessively, turbulent inside; the lift also was only mild, from 2 ft. to 7 ft./sec., and in a gay and youthful spirit I straightened up once or twice and went searching for better patches, started circling again, and behaved generally like a Dittmar.

"Suddenly the instruments went completely haywire. I worked out afterwards that I must have stalled: the nose drops, speed goes up; one corrects, but there is a lag in the air speed indicator, so one stalls again, more violently; the nose drops a second time, speed goes up higher; a third stall was followed by Bedlam. The turn indicator jammed hard left; the bank indicator hard right. The variometer showed its maximum of 25 ft./sec. descent, but as we were certainly losing height at over 150 ft./sec., maybe it had gone round six times. The A.S.I., however, exercised in me the greatest and most baleful fascination. It was registering a seemingly innocuous 40 m.p.h., but I had watched it with popping eyes achieve this by going twice round the dial. Hjordis, feeling as tight as a drum, was bellowing like a bull in considerable pain, and perhaps the most dominant of my kaleidoscopic emotions was a desire to move nothing more than half an inch at a time.

"It can be imagined that few actual seconds of this elapsed before I burst out of the cloud-base in a dive rather over the vertical, and in full view of a number of people on the ground. From this I gradually extricated her, and with the last of my excess speed zoomed back into the cloud. There was at that moment no spot in three-dimensional space which I would not have preferred; fortunately, the maw failed this time to clutch, and shortly afterwards we got clear.

"The heroes of this story are (*a*) Buxton (designer), and (*b*) Slingsby (constructor). I fill the rôle of the Foolish Virgin. For, spurred by this experience, I started to read up the subject.

"I discovered that the entertainment sprung on me is the High-speed Spiral Dive, and is a standard experience of blind-flying learners in their early stages.

"No machine can, in such a plight, stand up to forceful movements of the controls, nor can they be relied on, if they are dived at these speeds into any rapid horizontal or vertical acceleration of the air.

"The next section gives a few points which seemed to apply particularly to the sailplane pilot.

* * * *

"Part of the difficulty in obtaining accurate information regarding the difficulties of blind flight lies in most pilots' fear that an admission implies lack of skill in their capabilities as a pilot. Most pilots have on occasion flown for considerable periods in smooth cloud without getting into trouble, though they will probably admit that on those occasions the machine has really been left to fly itself.

"The basic need for training is easily shown by putting blindfolded pilots in a revolving chair and spinning it to and fro, and getting them to describe their sensations. The victim will soon come to realize the positively misleading ideas which his remaining senses give under these conditions.

"Even birds are unable to fly blind; pigeons have been blindfolded and released from aeroplanes, and in every case have proved helpless, doing spins and spiral dives.

"The average training time of thirty power pilots of over one thousand hours' experience was 5 hours 54 minutes. Whilst this included blind take-offs and landings, the glider pilot will always be flying blind in the most difficult conditions (*i.e.* unstable cloud), and will be required to do one of the most difficult evolutions, a constant and fairly steep turn. He must also be capable of getting out of a high-speed spiral dive, which will develop far more quickly than in an aeroplane, due to the cleaner lines of his machine. So his training must probably be to a fairly advanced standard. Also he will be unlikely to have so comprehensive a range of instruments. The artificial horizon, *e.g.* is a valuable saver of mental energy, but extremely expensive, and requires a high airspeed to operate.

"All this may sound like an attempt to put people off; in fact, however, the thing appears to be to abolish the pilot's erroneous confidence in his senses, and then build up an *instinctive* confidence in his instruments. Blind flying is a state of mind.

* * * *

"The moral of all this will no doubt be drawn by everyone according to his own taste. Some will say (some do say) the moral is 'DON'T.' Yet the subject has enormous possibilities for enhanced technique, enjoyment and beauty.

"What *is* definitely wrong is to go on happily flying into clouds and mist without adequate equipment and without a full knowledge of what is involved. For the deductions are:

"(1) That no machine built is strong enough to stand up to what *may* be inflicted upon it in clouds; although the chances of a break-up may no doubt be reduced to a minimum, the *risk* is unavoidable. (Moral: parachute).

"(2) That no human pilot can fly blind for long without instruments, although one may get away with it the first few times. (Moral: instruments).

"(3) That the successful use of blind-flying instruments is a difficult art. (Moral: lessons).

"When, however, someone comes down and airily confesses to having flown the club's ten-year-old moth-eaten Wobling intentionally into a cloud, he should be at once sent off to choose his site in the local cemetery.

"I think most pilots will agree that the reaction to this cloud-flying business must be 'Go ahead, but first realize fully *what it involves*, and take the necessary precautions'."

Irrespective of all that, better men than I have said elsewhere, I do *not* believe that really serious sailplane blind-flying can be safely self-taught. It is my firm opinion that no-one should venture in a big cloud in a sailplane until he has actually been given dual in recovery from spins under a hood, and if possible (though this is more hard to come by) in recovery from high-speed spiral dives.

Blind-flying is perfectly easy *until things go wrong*, when in the twinkling of an eye it becomes very difficult indeed unless one's instincts have been got under control by previous practise. And one cannot give oneself practise in spins or spiral dives, or in any way known to me, force oneself through the necessary, but unpleasant, process of learning to keep control of one's steed whilst subject to the nauseating and misleading sensations of vertigo. I may say that, for me, the Link trainer produced no symptoms—a genuine aircraft was essential.

In my own case, immunity is only temporary, and it was my

practice to have a short course in spins and high-speed dives under the hood every Spring, before the opening of the season. On each occasion the first evolution produced marked vertigo and sickness, but after several repetitions I became once more inoculated.

Others may not require so much, but the ordinary amateur pilot cannot expect to achieve the same standard of immunity as a commercial or service pilot who indulges in blind flying fairly regularly the year round.

Since writing the above, I have had further opportunity of investigation into the habits of cumulo-nimbus, and on June 19th, 1946, took the Weihe from Long Mynd to Molesworth. Although this flight was a complete failure in that I accomplished neither of the two objectives I set out for, it was, nevertheless, one of the most interesting I have ever made, and one about which I felt quite pleased with myself in the bargain. For it showed me that the six years, enforced lack of sailflying has not made me too old to go back and find the same fascination and the same tantalising *vista* of new worlds still awaiting conquering.

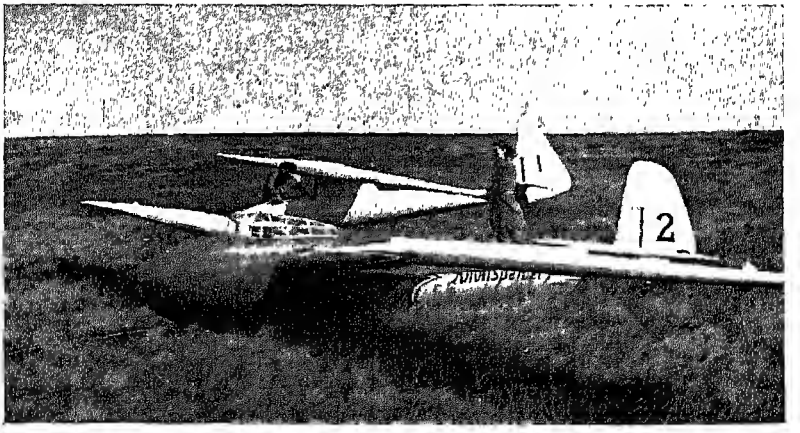


Fig. 58. *The Rhonsperber (owned by C. Nicholson and J. P. Dewsbery) about to be bungey-launched off hill-top. P. A. Wills with Hjordis (behind) having cockpit cover fitted.*

On the 19th the wind was light and W.N.W., almost straight up the hill. The forecast talked of cumulus, showers, occasional thunder, and such-like intoxicating delights, but a slight shadow was cast by talk of a small polar low over Bristol travelling S.E. and then E., with associated low cloud.

However, I decided to declare Cambridge as a goal, and also it was an obvious day to go for altitude on the way.

I took off at 11.30, the wind was just strong enough for a bungey launch and a very gentle climb up to 400 feet. Then just north of the club-house I struck lift up to 10 ft./sec., and twelve minutes after take-off, was at cloud-base, 2000 feet above take-off altitude and half-way back to Church Stretton.

I switched on the turn-and-bank indicator, and hardly switched it off again for three hours.

I circled up in fairly gentle lift in this first cloud to 3500 feet. (I will talk in general in altitudes above take-off. To get altitude above sea-level add the height of the Mynd, 1350 feet, throughout), and then set off on my course, approximately 105° magnetic, still in cloud.

The main difficulty of the day was that the clouds were in large untidy lumps all over the place, and rather widely spaced apart, and cloud-base was only just over 3000 feet above sea-level, a scandalous state of affairs for English mid-summer weather.

Thus it was necessary to keep above cloud-base as much as possible, and this I achieved, being above this level and mostly in cloud for three hours out of the four and a quarter hours of the flight.

But in this condition one hardly ever got a good view of the clouds around; when one came out for a few minutes ragged and titanic masses of tumbled cloud were all round, and one couldn't see the wood for the trees.

It was also necessary on these brief occasions to locate oneself by a glimpse of the shadowed world through the hole beneath one, but fortunately my A.T.A. past stood me in good stead, as in the last six years I have come to know England from above in a pretty comprehensive way.

I came out of my first cloud over the Southern end of Wenlock Edge, and almost immediately entered another just ahead, from which rain was falling fairly heavily. The lift was ahead of the

rain, which I first flew through, and circled up rather slowly to 3500 feet again. Here, to my dismay, my turn-and-bank stopped working, and when from the complaining noises from the Weihe I realised this, I clapped on the air-brakes and let her sort herself out, whilst I fiddled about with the 4½-volt torch battery in its container, eventually to my relief, finding a faulty contact, and getting the instrument going again.

I had lost about 600 feet doing this, but on putting off the dive-brakes, found I was still in lift, and started circling again.

My system on the Weihe is as follows. First set the tail-trimmer so that the machine flies hands-off at 48 m.p.h. (10 m.p.h. above normal). Keep this trim unchanged during the blind-flight, circle about rate 2. When the speed tends to build up, rudder back until the turn needle is central again, ease off the speed on the elevator, and start circling again. *Never try to ease off the speed whilst still in the turn*; that way lies the High-Speed Spiral Dive, to which I give respectful capitals, having met it once unexpectedly face to face round a corner. Note that for blind-flying a sailplane *must* be stable in pitch, either positively like the Minimoa, or neutrally like the Weihe. It must also be stable in yaw and roll, but pitch stability is really vital from the safety point of view.

I now found myself climbing fairly well at about 10 ft./sec., but the air was not as smooth as in the more powerful up-currents I have met. In fact I rather think now that the stronger the up-current in a cloud, the smoother it is, in a rather sinister kind of way, and of course the higher it goes.

At 6000 feet we started to ice up, ice building up forwards on all protuberances and on the leading edge of the wing.

The pressure side of the pitot head grew its ice-straw, just as in the old days, the war seeming to have made little impression on the habits of cumulo-nimbus; and the rubber nail-brush of ice sprouted forwards on the wing.

At 7000 feet we reached rough air and the apparent top of the local lift, so on to course again. As we came down below the 6000 feet level the A.S.I. started to flicker and die, as the ice-straw started to melt, so I kept straight on the turn-and-bank, and let the Weihe fly herself until at 4500 feet the lump of ice

melted enough to blow off, struck the wind-screen with a resounding crack, and disappeared, leaving me instead with a registering air-speed, which exchange I much preferred.

I now emerged after some thirty minutes blind, and found myself just east of Wyre Forest, near Kidderminster.

I fiddled about for some time in and out of rather unsatisfactory lumps of medium-sized cumulus, never high enough to be really at ease, until I worked my way as far as Honiley, when I saw to the north towards Elmdonr a towering mass of cloud towards which I flew.

Gaining in cunning, I didn't start circling at the first piece of lift I found under its edge, as I had come to the conclusion that this only took one up into the edges of the main mass of the cloud, but flew on through this and a few down-currents, until I calculated I was nearer the real bulk overhead.

I then started circling in lift which gradually built up to 15 ft./sec.

At 6000 feet we re-assumed our excrescences of ice, and at 8000 feet a fine powder of snow started to penetrate crevices of the cockpit cover. At 8300 feet I started to get out of the cone of lift, probably by faulty circling, and as I was now shivering with cold, I straightened once more on my course, and set off in a glide at 50 m.p.h.

Back below 6000 feet again, the A.S.I. faltered and went out, and now I was faced with quite a problem. If I encountered big lift again before I got low enough to recover my A.S.I. I was in no condition to meet it. I would have to rely on my air-brakes to get me out. However, it was a bridge which did not have to be crossed, because I came down, lost my ice-lump at 4500 feet, and emerged for a brief four minutes at 3600 feet, just time to locate myself as north of Coventry, before once more flying into the side of another large cloud mass.

Soon I struck big stuff. The green ball went up to 15, 20, 25 ft./sec., and then disappeared in the top of the tube. I passed again through the icing level, then the powdery snow brought the shivers on again. This time it came in in quantities, covered the inside of the cockpit, and I had to wipe it off the faces of the instruments.

It also covered a good deal of me, got into my shoes, and in general I must have looked like a modern, if rather cramped, edition of Father Christmas.

I started to suck a toffee, a trick I find rather consoling in these conditions, and suddenly bit on a hard lump, which investigation showed to be a bit of tooth.

Over the constricted panorama of my rather ascetic little world was superimposed a vision of my dentist's waiting-room, which sports a particularly opulent line of large electric fire. This vision of my earthly life was rather comforting.

At 11,000 feet (12,000 feet above sea-level) I again met turbulent air, and having no clues about the sort of shape of the cloud I was in, could do no more, but once more set sail for Cambridge, leaving another 3000 feet to go to equal my previous best.

Once more through the reverse sequence, bunged-up A.S.I. and all, for over half an hour I sailed along through grey and lifeless cloud, until I came out and found myself pretty well on my course near Kettering.

Ahead the cumulus didn't look very hopeful, but I struggled on until, south of Thrapston I came to the very last cumulus, and found the remaining twenty-five miles ahead absolutely grey and lifeless. Evidently Bristol's Polar Low had done me dirt. I was foiled.

At least four airfields were in sight, so I picked the one that showed signs of occupation, approached it at 110 m.p.h., and landed at 1545 hours, at Molesworth, twenty-five miles short of my goal.

Where are we now? When on the next day I got back to the Mynd and discussed with Bira his flight that day in cumulo-nimbus to 9000 odd feet, I began to see that at last we have come to the point where we can begin to describe some general features in regard to flights in these big cumulo-nimbus clouds. And once one begins to know what to expect, the whole problem becomes much less awe-inspiring, though I should be the last to suggest that we should ever treat these many million horse-powered giants with anything but the most sincere respect.

But the various phases one goes through on both the up and down parts of the flight seem each time closely similar. One problem and its cure I should like the answer to at once please. Why on earth does the pitot-head icicle grow forwards with a hollow centre, like a straw? And how can one dissolve or break

that straw off so that on the way down it doesn't temporarily cause the defection of one's A.S.I. at a potentially awkward moment? Don't ask the sailplane to carry a vast accumulator if it can be helped, though this must be faced if it is the only solution.

Note that it does not seem necessary to prevent the ice forming, but only to detach or break off the straw, once one is safely above icing level.

If an accumulator must be carried, it must, but as oxygen is clearly not now far ahead, the poor old sailplane looks like becoming a beast of burden.

One word of warning about oxygen. Many pilots say gaily "Oh, I have been up to 20,000 feet without oxygen, and was perfectly all right". This attitude was overcome at the expense of many lives and much patience during the war.

Oxygen lack produces much the same symptoms as alcohol—a feeling of gay well-being allied to a progressive deterioration of the higher reasoning powers—the aftermath in serious cases being a headache and complete loss of memory of what happened.

In an aeroplane at 20,000 feet the higher reasoning powers may not always be required. In a sailplane in a cumulo-nimbus, flying blind on a simple turn-and-bank indicator, they are. The interpretation of the instruments is not natural, but highly inferential. My own guess is that somewhere between 15,000 and 17,000 feet is the top limit for the normally aspirated husband and father.

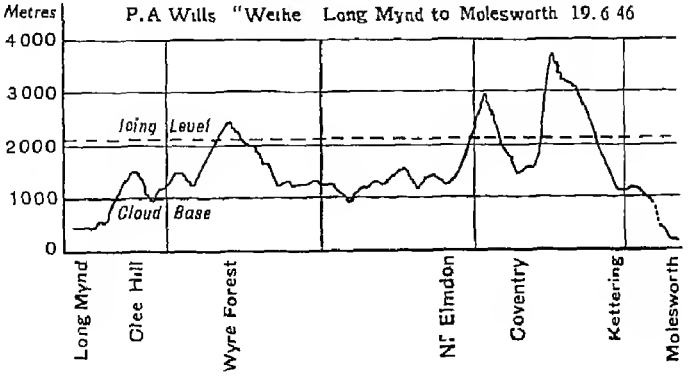


Diagram 19A

Chapter 8

SOME GEOLOGICAL INFLUENCES

It has always been recognised by sailplane pilots that the production of local thermals is affected by contrast in ground surface conditions, but very little has so far been done to analyse the factors involved.

When pilots have been searching round for lift they have looked for contrast in the form of cornfields surrounded by woods, etc., and experience has inevitably brought successful results in its wake, but on the whole, the methods employed have been haphazard: there is so much more to be taken into consideration than mere visible, and apparent contrast. For instance, the contrast between a sunlit town or village surrounded by green fields can be nullified for a short while after a sharp shower.

It will never be really practicable to make any fast rules on the likely sources of thermals, as not only do these sources continually change due to the weather and time of day, but also the frequency with which thermal currents form and break away.

The following notes indicate some of the forms of contrast which must be considered whenever thermals are being looked for on the ground. The list may appear forbiddingly long, but the first two points, which are the most important, cover some of the others.

(1) Contrast between Surface Colours. The location of thermals, if controlled by this factor *alone*, would vary throughout the day. With regard to soil in the dry state, the rate of heating depends on the colour, and black or very dark soils would rate highest, these would include such examples as coal measures and fen soils. Medium-coloured soils such as sand, clay, and alluvium would follow, and the light-coloured soils like chalk, granite and limestone would be last. This means that if only the bare soil is being considered, chalk, for instance, would not start producing thermals until later in the day than the darker soils, or going to extremes, if a large chalk area was suitably dotted with frequent patches of black soil, the chalk might never produce any thermals at all, although chalky soil is quite a good thermal producer.

When considering surface colours generally, other factors have also to be noted, for example; although woods are usually darker than the surrounding land, they often do not give off thermals until quite late in the day, partly because there is a considerable volume of cool air in the shade beneath the trees which also has to be heated up, and partly because of the higher humidity usually prevailing in woods and forests.

(2) Contrast between surface dampness. This is a more difficult form of contrast to look for, as in many cases, it is not easily visible. Thermals will naturally come more quickly off dry patches of ground than damp, due to the cooling caused through the evaporation of moisture, although any thermal source might well be improved by being surrounded by damp ground: this would increase the surface temperature contrast, as well as enabling the thermal bubble a good moisture supply to draw from, which would be more conducive to good cumulus growth. (More will be said on this point under thunderstorms).

Three points that the pilot should look for when trying to determine what contrast is present in surface moisture are (*a*) Whether a local shower, or rainstorm has recently passed over the area: in towns this would be easy to see by the shine on streets and roofs, but over open countryside it is more difficult unless the dry colour of the soil of the district is known, as this invariably darkens when wet. (*b*) What signs are visible of recent flooding of the area or, of extensive water under the immediate surface; this latter would be fairly easily noticeable in the greenness of the fields, and the presence of darker patches of coarse marsh plants. Such areas should be avoided. (*c*) Rate of drainage: this entails a knowledge of the various surface soils of the district flown over as all soils drain at different rates; such knowledge would give the pilot a greater chance of remaining in the air when he cannot avoid having to cross extensive areas of apparently unsuitable land.

(3) Contrast in Geological Strata. This is really an amplification of points 1 and 2, as the changing surface soils provide both contrast in colour and moisture. But the effectiveness of thermal production from the bare soils will vary according to whether colour (rate of heating), or speed of drainage, becomes the controlling factor. If the soils are absolutely dry, the order in which they fall might be, as stated in Point 1, black soils,

intermediate soils, and finally light soils; but if they were not dry, the coarseness of the grain of the soil would dominate, which would mean that sand, etc., would rate higher for thermal productivity than say, the fen soils, white clay would descend to the bottom of the list.

Although the term "rate of drainage" has been used above, it is the amount of water drained away by the soil in a given time that is important; for instance, a clay soil actually drains quite quickly, but the amount drained away is very small compared with sand, so that after rain the sand would be able to produce thermal currents much sooner than the clay.

(4) Contrast between Local Surface Variations. The effect of such contrast will be to at once modify the factors given in Point 3, as the soils are rarely bare, being extensively covered by green plants, which tend to even out any marked contrast. In widespread green areas the greatest possibility of thermals will exist shortly after rain from the coarser-grained soils, which dry out more quickly. After several days of dry weather, however, the plants and grass will have dried out all the soils to nearly the same extent, and the contrast will then almost disappear. Surface contrast will of course still be apparent between ploughed and green fields, or the latter and fields of ripe corn. Villages and towns become excellent sources of local thermals during very dry weather when the uniformity of the surface soil moisture is most marked. On very light-coloured soils, such as chalk, dry soil cover (crops, etc.), greatly improves the chances and quality of thermals.

(5) Contrast between Sunny and Shady Patches on the Ground Caused by the Shadow of the Clouds Above. An easily seen but transient thermal source; it is more effective when large ground areas are in shadow with isolated sunlit patches.

Members of the Cambridge University Gliding Club were among others who were carrying out experiments on thermals before the war; they would launch a sailplane just as the shadow of a cloud passed across the landing ground, and very frequently indeed they connected with lift, as though the cooled air and ground surface caused by the shadow was continually undercutting and lifting the warmer air immediately in front of this advancing "column". Experiments, due to the war, were never continued far enough to determine the exact conditions necessary for this occurrence; whether, for instance, these

thermals only appeared in certain combinations of wind direction and sun position, or not.

(6) Contrast between Sheltered and Exposed Regions (wind shadow thermals). Sometimes the wind is strong enough to blow away the potential thermal bubble before it is able to attain sufficient temperature difference to become unstable. Then sheltered valleys and hollows will become thermal producers even though they may not seem suitable when other factors are taken into consideration; the more the surrounding land is cooled by the wind the better such sources will become. It should be remembered, however, that due to the general turbulence prevailing up to 1500-2000 feet on windy days, such thermals as are produced will also be broken and rough in the lower levels.

This contrast is also apparent in the late afternoon, when the air is cooling due to the decline of the sun. Then south-westerly slopes or hollows often produce thermals after most other sources have ceased for the day.

(7) Contrast between Land and Sea Temperatures. This produces the well-known Sea Breeze Effect, when the wind blows from the cool sea to replace the warm air which is rising from the land during the day. The reverse occurs at night when the sea becomes relatively warmer than the land due to radiation.

Sometimes the main wind of the prevailing weather system blowing over the land may flow at an opposing angle to the sea breeze and be strong enough to become a counter force. Where the two contact there may be formed a ridge of rising air roughly parallel to the general line of the coast, the actual position depending on the relative strength of the two winds, but it usually seems to lie two or three miles out over the sea. P. A. Wills made use of such a line of lift over the sea between Bridport and Lyme Regis on each of two flights made in a fresh to strong N.E. wind in anti-cyclonic conditions.

Frequency of Thermals. This depends largely on the relative heat of the sun and the temperature of the air in contact with the ground. In the morning when the air is cool thermal bubbles quickly reach sufficient temperature difference to become unstable, and as a result rise while they are still small, and with a high frequency. As the air warms up towards the middle of the day, it takes longer for the potential thermals to reach

instability and so they become larger and less frequent. During the late afternoon when the heat of the sun is beginning to decline, thermals will remain large, but will occur less often. They will also be weaker.

The above brief descriptions have been an attempt to separate the different factors involved in the production of thermals from the ground, so that possible sources may be more accurately valued when looking for lift during a cross-country flight, when there is no obvious and visible cloud lift available. In actual practice, however, it is necessary that the varying conditions given above should be considered together.

This will be made easier if the geological surface conditions of the country to be flown over are known to the pilot. This can be done, of course, by a careful study of the quarter-inch Surface Geological maps which give a clear indication of surface deposits, but the ideal would be to have the information incorporated into a simplified version (as regards marking of small villages and place names, etc.) of the quarter-inch Aviation map.

Diag. 20 shows the cross-country flights of fifty miles or over, unless of special interest, plotted on a map which indicates some of the more extensive soil strata. The study of such a map will illustrate several of the points made in this chapter. Perhaps one of the most interesting is caused by the belt of oolitic limestone which lies across England from Bridport and Chippenham, following roughly the line of the Cotswolds, to Huntingdon and then northwards until it peters out some miles north of Lincoln. It then reappears to the north-east of Thirsk in Yorkshire. Few flights have succeeded in crossing this area where more than a few miles wide, unless the pilots have been carried over it in lift gained before the area was reached, or have obtained lift from Local Sources. This great expanse, although composed of limestone, which is fairly quick draining and seemingly suitable for the production of thermals, has a thin and broken layer of clay spread extensively over its surface, and it must be partly due to this that it tends to be inhospitable to sailplane pilots. The soil is also light in colour, and so will not heat rapidly.

P. A. Wills on two of his long flights into the West Country went round the Blackmore Vale which lies in this stratum as "the . . . country seemed greener and moister than elsewhere;

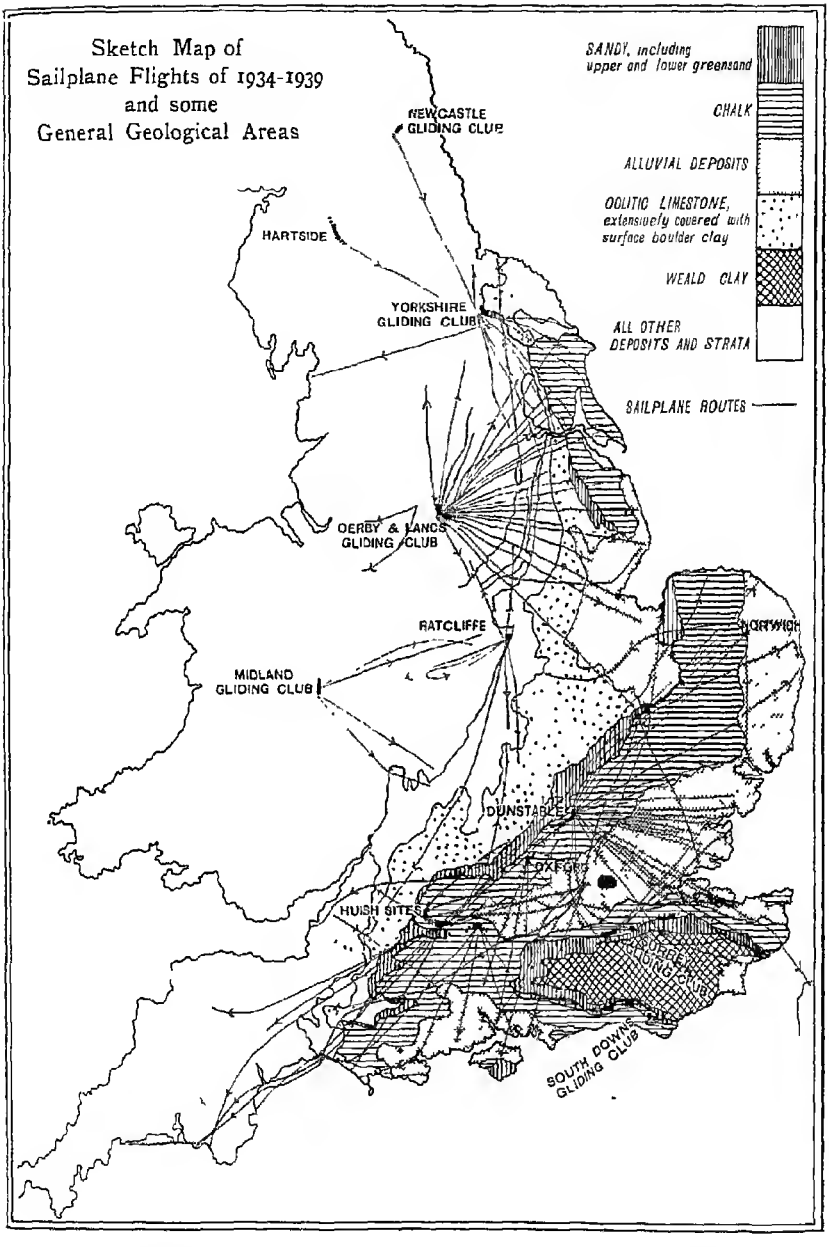


Diagram 20. *Sketch map of sailplane flights over forty miles in length, showing tendencies to lie over sandy, chalk and alluvial areas. The mass of flights from Derby were mostly made at National Contests, but it appears that narrow strips of different soils providing continuous contrast may be favourable to cross-country flying. The deposits and strata not marked on this small map have been omitted as they are mostly broken and split up and could not be shown clearly.*

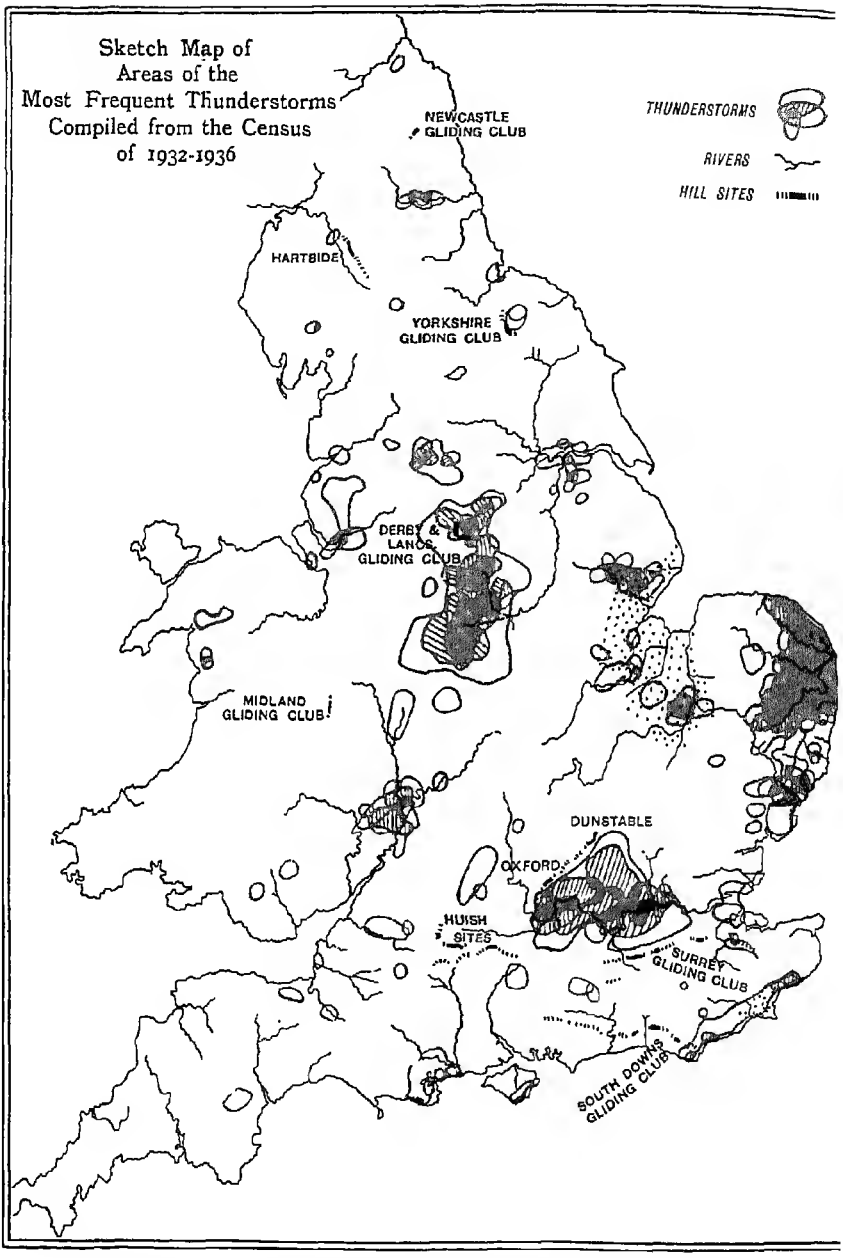
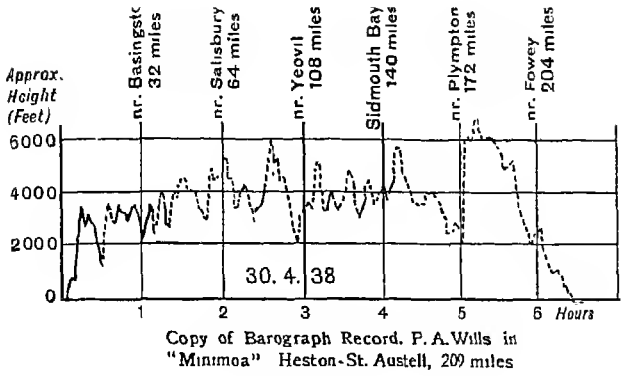


Diagram 22. *The thunderstorm areas shown above are the positions where the storms broke. It would seem that two main conditions are necessary for their development—considerable areas of dry ground which is suitable for thermal production (this may be extensive built-up area or natural sources) plus quantities of available moisture. The two conditions must be present, but must be separate. (The dotted areas show marsh land.)*



Copy of Barograph Record. P. A. Wills in "Minimoa" Heston-St. Austell, 209 miles

Diagram 21

certainly it was not so generous of upcurrents". The whole of this part of the countryside had had no recent rain, the flight being made in anti-cyclonic conditions on 18th April, 1938. The next flight on the 30th of the same month, under similar conditions, gave "Now came to Blackmore Vale . . . rather cold to strangers. It was again". On both flights Wills made for a sloping wood near Yeovil aerodrome and on both occasions obtained lift. Yeovil is on the far boundary of the stratum, and the sloping wood an isolated Local Source, but it is interesting that no lift was found on either occasion while flying over the part that he could not avoid.

Another feature which may be noticed in diagram 20 is that the narrow sandy strips which tend to run approximately along the faces of many of the chalk downs in southern England provide excellent soaring routes or lanes, other weather conditions being equal. The four gliding sites of Huish, Aston Rowant, Dunstable, and Cambridge lie on an almost continuous sandy strip, or immediately behind it, on the chalk. This particular strip runs north-east and south-west and is faced on its north-western boundary by the rather unwelcome area previously described. A glance at the plots of sailplane flights over this strip or lane, shows that it has been used as such to good effect, as there are seventeen flights along it. Some of these extend farther, to or beyond, the Norwich Club, and the majority start and terminate on one or other of the club sites, showing the existence of conditions suitable for soaring all the way along.

Another similar area where excellent thermal conditions may be found, is along a similar sandy strip, which is sandwiched between the clayey weald of Kent and Surrey and the chalk uplands of the North Downs. On any day suitable to thermal production, even if the wind is northerly and blowing down the face of the downs, the whole length of this sand strip is dotted with many active cumuli, while practically nothing comes off the Weald.

Another example of geological contrast occurs in G. E. Collins' flight from Dunstable to Rayleigh on April 22nd, 1934 (52 miles). He was flying in the air behind an occluded cold front which had passed the day before. Thermal activity was only fairly good. After reaching Broxbourne there seemed to be little in the way of good clouds farther ahead, except above a cluster of small villages away to the north. These villages all having the name of 'Roding', are each situated on a patch of sand in the midst of an area predominantly clay. Lift from them enabled him to enter cloud base at 4900 feet and continue the flight to Rayleigh.

Some information may also be discovered from a study of the more predominant thunderstorm areas in the country. Such areas are interesting in that they apparently bear no relation whatever to the geological, population, land survey, vegetation or contour maps. The only one which can be said to fit is the map of inland surface-water supply. Each of the predominant thunderstorm areas shown lies over an area of a large river and its many tributaries, or an area of extensively irrigated land. But in addition, such areas need to be able to heat up quickly in relation to the surrounding countryside. It will be seen for instance, that two of the biggest thunderstorm areas lie in large built-up regions, which are also well supplied with rivers and reservoirs (Diag. 22).

The census from which this map was compiled was only taken from 1932-1936.

In 1936 the Poles compiled a thermal source map, and maps showing best cross-country routes for north and south and for east and west winds. They reckoned that the final controlling factor in the production of thermals from ground sources was that of the underground water supply, which would directly affect the degree of dampness, and rate of drainage.

Chapter 9

REVIEW OF SAILPLANES

SINCE gliding was restarted in Germany after the last war, there has not been much change in basic sailplane design and construction; there have been vast improvements, of course, in both flight performance and strength, but the vast majority of sailplanes today still follow the same orthodox layout that they did nearly twenty-five years ago.

The Blaue Maus and the Vampyr of 1922 were the forerunners of today's sailplanes. They were both wood and fabric machines with cantilever wings, and although the Blaue Maus had three wing spars, the Vampyr had the single spar wing with the torsion resisting leading edge common in modern design. The Vampyr also possessed a wing of fairly high aspect ratio.

These two machines gave way to those with an oval monocoque streamlined fuselage and a high cantilever wing in which the wide centre section was of parallel chord and the outer portions of the wing elliptical. There was usually no dihedral angle.

The cockpits were still generally open, although some had covers which fitted round the pilot's neck as tightly as a collar. The Westpreussen and Lore were examples of sailplanes of the later 1920's.

The Germans were almost the only people to be developing sailplanes on any scale at this stage, and they soon found that as their machines improved, but at the same time grew larger and more unwieldy, it was necessary to introduce some medium-performance machines for training in soaring, as well as some basic flight trainers. The Professor was one of the first machines designed as suitable for post 'C' pilots, although it was apt to be rather tricky to handle.

About 1930 sailplanes appeared which could be most favourably compared with those of today, except that they lacked any real speed range, due partly to the high-lift slow-speed wing sections generally in use, and low wing loadings.

It was during this period, and the few years following, that wing spans (and aspect ratios) gradually increased, it being quite normal for a single-seater sailplane to have a span of 60 feet or over. The Wien, of 63-ft. span, and the Fafnir, of 62 ft. 4 in., were examples, and this tendency culminated in

Kronfeld's Austria of 98 ft. 10 in. span. These machines of great span had certain disadvantages. They were unwieldy near the ground due to the low ground clearance of the long wing, and the wings were inclined to be "whippy", due to the difficulty of obtaining stiffness without heaviness and an excessively thick spar. The first of these faults was overcome by gulling the wing, and this became a fashion in the middle 1930's.

Gradually spans were reduced again until the most usual for high-performance single-seaters was, and still is, about 50-55 feet, examples being Minimoa, 54 ft., Atalante, 52 ft. 6 in., Meise, 49 ft. 3 in. Although the span of the Weihe is practically 60 feet. This enabled the wing to be made stiffer, but was also accompanied by an increase in wing loading, and also of stalling speed, which was a factor to be desired in high-performance machines as it helped to increase the speed range or penetration. This was necessary to enable pilots to obtain the greatest possible distance during the hours of thermal activity, usually limited to six or seven in Europe on even the best days. Already the better pilots had proved that they could frequently remain airborne for this period in good conditions, but the mileage covered was not high, due to the slowness of their machines; to push up the speed was to increase the rate of sink, and thereby waste available lift. The carriage of a water ballast tank with jettison tap was also started in the later 1930's to increase the speed ranges during the hours when conditions were at their strongest. As the lift became feebler towards evening, the water was jettisoned to decrease the sinking speed at the expense of the high-speed qualities and gliding angle.

The increase in wing loading, which carried with it the flat high-speed glide, was compensated for by lift spoilers or flaps for landing and approach purposes. These became generally fitted to high-performance craft during the middle 1930's, and spoilers or some type of air brake are fitted as standard today.

Development of trainers ran parallel to the development of sailplanes, and performance naturally has remained about the same. The greatest change in trainers has been in their improved suitability for the job, including safer handling qualities. As the years passed some sailplanes, types which were once looked on as high-performance machines, have become advanced trainers as the general qualities of the former types have been improved.

Chapter 10

LAYOUT

THIS chapter has been written for the person who wishes to design and construct his own machine, or who wishes to have a machine built for him by a manufacturer to his own specification. The mathematical and stressing side is not entered into, as not only would this require a volume in itself, but it is infinitely better and safer for everyone concerned if this job is done by a professional who knows the subject thoroughly. There are always people who are ready to decry the "backyard glider", when a home designed and built machine, however good, gets itself broken. It is also assumed that the reader is familiar with the elementary theory of flight. The drawings and figures in chapter 9 may be used for reference as examples of typical and well tried layouts, to avoid duplication here.

The following will try to deal with some of the considerations peculiar to gliders and sailplanes. The amateur should always endeavour to keep in mind that good designs are simple, and practical, and should not be complicated, or full of gadgets (Fig. 71).

FIRST CONSIDERATIONS

The pilot should first reckon how much experience he will have as a pilot by the time his creation is finished. He will probably want a machine with as high a performance as possible, but at the same time not too advanced for his flying hours as, unless his piloting ability is exceptional, early mistakes may prove expensive! If the site on which he will make these early flights possesses a large and easy landing ground, he may decide to risk this lack of skill, but if he is tied to a restricted site, he should be content with easy handling properties in his machine.

Thought should be given to the place where the machine is to be built and housed, and what type of car will be available for towing it: this will affect the size of the machine, and therefore its performance. More than one amateur has built a perfectly good machine in his drawing room and then not

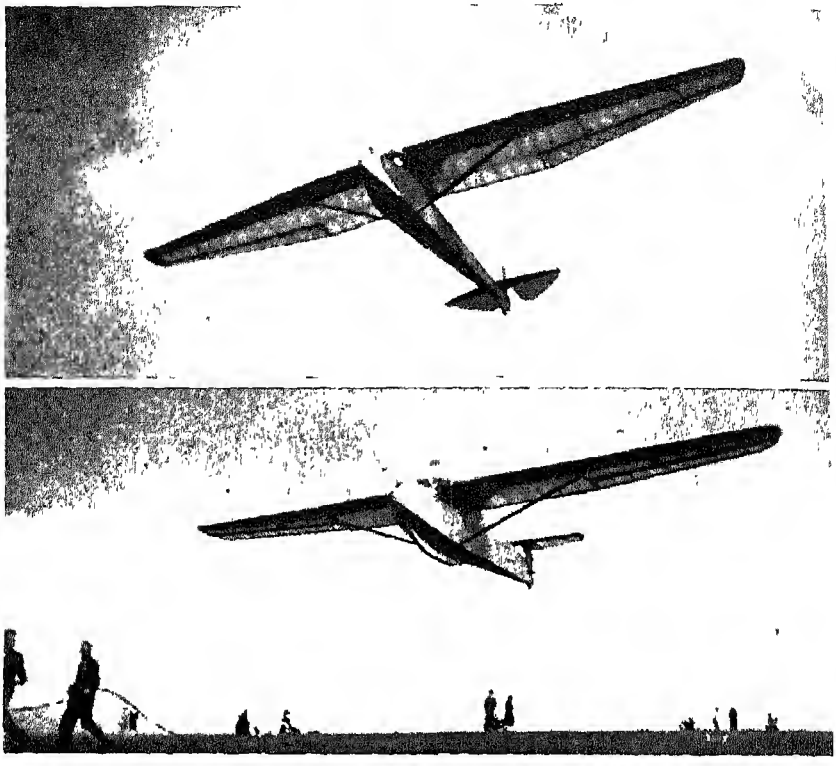


Fig. 71. *Two medium-performance amateur British sailplanes. (Top) The Wren, designed by Corporal Manuel, R.A.F., in 1931, and (below) The Camel, designed by J. S. Sproule and A. Ivanoff (1938). It will be seen that both are single-spar strut-braced machines with slabsided fuselages for simplicity in design, construction and repair.*

been able to get it out through either window or door. The wing may even have to be built in three pieces, or the span limited.

The use to which the machine is to be put, and the performance desired, should be considered next. Every sailplane must be a compromise job, as it is not possible to obtain the highest quality in one direction without partially sacrificing some other desirable characteristic. This point of compromise will be readily seen from the brief specifications of classes of

gliders and sailplanes below, or by referring to some examples of aircraft in these classes in chapter 9

GLIDER AND SAILPLANE CATEGORIES

Solo primary trainer. This type must above all be free from vices and inherently stable; it should be able to fly slowly, not be too light on the controls, nor pick up speed easily. It should have a perfect view for the pilot, and must be cheap to construct and repair. It should be designed to cause the pupil as little personal damage as possible if he is unfortunate enough to break it.

Solo secondary trainer. This needs to be as free from vices as the primary, but may be more responsive on the controls and need not have such a steep angle of glide; a gliding angle up to 1 in 18 will not matter provided the machine does not pick up speed when flown fast or dived. Ease of repair is essential.

Advanced trainer, club or private medium performance sailplane. This class of sailplane still needs to be free from any trickiness as it will be flown by pilots without much experience, or experienced pilots who have been off flying for some time. It should be easy to repair, and minor repairs should be simple even for the amateur. It should be light and responsive on the controls, have a fairly low sinking speed and a good gliding angle at low speed. It is not very desirable that it should pick up speed rapidly, and so will not be suitable for distance flying except under easy conditions. This type of machine is fairly simple to design as the use of a good high-lift wing section will help to give mild stall characteristics, low sinking speed and a poor speed range.

Medium-high-performance club or private sailplane. This is where the real problems in design start. The pilot at this stage should be capable of dealing with a sailplane having a flat angle of glide which picks up speed quite easily, but he does not desire any viciousness when flying slowly. He wants a low sinking speed for light wind and flat conditions, and yet quite a good speed range for distance flying. Repairs should not be required often, and so the more expensive type of monocoque fuselage should be incorporated, instead of the slabsided or hexagonal type normally used on trainers. For club use, it is advisable to have machines in this class of the single-strut,

braced wing type. Fully cantilever machines are more easily subject to strain on the root fittings, and have a more expensive spar.

Long distance sailplane. This is a specialist type of high-performance sailplane. Above all it needs a good speed range, or penetration, and must be able to pick up speed rapidly for fast flying in between lift areas, and be able to cruise at a high speed without increasing the rate of sink abnormally. This will be difficult to attain without sacrifice in some other direction, probably either handling qualities or cost. At the same time it needs to be able to fly slowly enough to get the maximum height from small patches of lift. This characteristic becomes necessary when using the modern technique of not circling when at a good cruising height, but of flying on a straight course and slowing the machine up rapidly when entering lift, in order to remain in it for the longest possible time without altering course. Speed is immediately increased again as the lift area is passed.

In a machine of this type a fairly high wing loading and fast section can be used, as, provided adequate glide steepeners are fitted, the landing speed need not be kept very low. The machine should obviously be of the cleanest possible design as the quality of penetration is the main objective, and this will naturally add both expense and weight. The addition of an 8–10 gallon water tank which increases the all-up weight, will also improve the gliding angle. It should be fitted with a jettison tap for use prior to landing or to help the sinking speed at the expense of the gliding angle when the lift becomes weak later in the day. Another device sometimes used to increase the speed range is the adjustable aileron, which can be raised above the normal position for high-speed flying and lowered when it is desired to fly more slowly.

The fuselage should be clean and well designed, but it is very important that the pilot should have really adequate space in the cockpit, and plenty of provision for stowing such items as maps, food, drink, notebooks or camera, etc. He should have a really good view so that there is at no time any feeling of strain for this reason. Long distance flights may last as long as the soarable conditions, anything from five to eight hours, and to sit for this time, cramped, strained, or hungry, not only takes the pleasure from the flight, but may have a serious effect upon the efficiency of the pilot.

As weight saving is not the primary consideration in sailplanes of this class such refinements as a landing wheel and brake should be fitted.

Altitude, Out-and-Return, and high-performance general purpose sailplane. This type is really an improved version of the medium-high-performance club or private sailplane. The main differences being that it would most likely have a fully cantilever wing, and that the gliding angle should be better relative to the sinking speed. The machine should be naturally stable, as it may be used for extensive blind flying in turbulent cloud. Once again a really adequate cockpit layout should be used. The Weihe is a good example of this class.

Training or General Purpose Club two-seater. A two-seater of this type, when used for training, should be as light as possible on the controls and have characteristics similar to the types of solo sailplane that the pilot will be flying after he has done his basic training. The instructor should have an adequate view.

The speed range of this class of machine need not be very good, but the sinking speed should be low, in order that each training flight may last as long as possible, and the stall characteristics mild and viceless. For training it is better that a machine of this type should have open cockpits, although if used for passenger carrying, optional transparent covers may be useful.

High-performance two-seater. This is very similar to the single-seater of similar type, except that it would naturally be bigger, heavier and less handy. In either class of two-seater, the location of the seats may be either tandem, or side-by-side, although on a sailplane which may be used for serious high-performance flying by a "crew", the seating could well be staggered, which, except for the more complicated instalment of dual control, gives some of the advantages of both seating arrangements.

Other classes of sailplanes exist, such as flying boat sailplanes, tailless and tail-first machines and other experimental types, but these are beyond the range of this book.

General Layout

This will be divided up under wings, fuselage and undercarriage, tail unit, rigging, spoilers, etc., and cockpit.

THE WINGS

The wing plan. The wing plan may be one of two basic types; either having a parallel chord from root to tip, or tapering. Often a combination of the two is used.

Parallel chord wings are now really used only on trainers or low-performance sailplanes. They are cheap to build and easy to repair, as all the ribs are made on the same size jig; also a greater wing area can be obtained for any given span than on a taper wing (unless the root chord is to be abnormally wide) and this may be very suitable on a trainer where handiness is required, rather than superior performance. As the span is

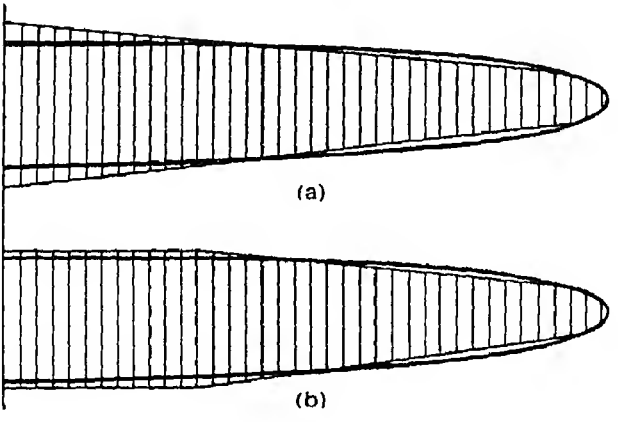


Diagram 33

increased, however, not only does the weight become high, but the efficiency of the wing becomes less.

For high-performance sailplanes, an elliptical wing is usually reckoned to be the most efficient shape, although it is more expensive both to build and repair, but as sailplanes of this class normally have wings of high aspect ratio,* a wing of straight taper will be found to be very nearly as efficient, and considerably cheaper and more simple to construct (Diag. 33). The taper wing enables the loading and weight of the wing to be decreased uniformly toward the tip (Fig. 72), which obviates the necessity of designing an abnormally strong and heavy

**Aspect ratio.* Ratio of span to mean chord. With parallel wings it is found by dividing the span by the chord. On taper wings divide the span squared by the wing area. Typical aspect ratios for different classes of machine will be found in Chapter 9 and Appendix I.

structure. The advantage of a high aspect ratio results in the reduction of end-losses, or the losses in efficiency due to turbulence at the wing tip caused by the lower pressure air flow from above the wing meeting the higher pressure air-flow from below the wing.

For a practical general purpose sailplane with a medium-high-performance, the best all-round results would be obtained by having a strut-braced single-spar wing using parallel chord as far as the strut position, and then tapering to the tip. This

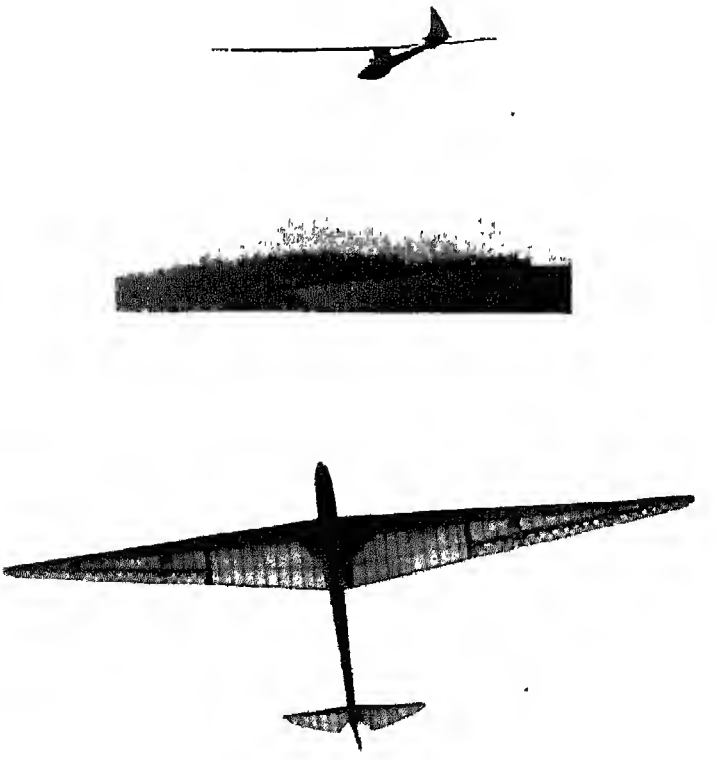


Fig. 72. *Hjordis: a British designed high-performance sailplane of a few years ago; and Rhonadler: a good example of wing of straight taper and high aspect ratio.*

enables the spar structure to be kept fairly light, and a thinner wing section used, which would result in lower drag: it also cuts down the number of different sized ribs to be built. (*See* the drawings of the Gull, G.B.II, and Schweizer in chapter 9, this layout has been used effectively on all these types).

When deciding on the wing plan to be used, the height of the wing tips above the ground should be considered. This factor, in addition to stowage problems, may limit the span; an unwieldy sailplane can be an expensive item, as it will be difficult to land in restricted spaces and on uneven ground.

Dihedral Angle

One way of increasing the tip-ground clearance is to gull the wings, that is, to give them a large dihedral angle for about one-third of the semi-span outwards from the wing root, and then reduce the dihedral angle to nil. This, of course, complicates the spar structure, and it is simpler to give an overall dihedral angle of 1-3° to a high, or shoulder, wing arrangement. This dihedral angle must not be overdone, as a sailplane with a high wing position is fairly stable, and a gulled wing, or large dihedral angle, will add to this stability, necessitating increased aileron area to overcome it. This in turn usually results in sluggish and heavy lateral control.

Sweep Back

When the distribution of flight load is not constant, such as in a tandem two-seater, or where stable flying characteristics are required, it may be desired to give the wing a certain amount of sweep back (*see* the Kranich and Falcon—Chapter 9) to increase the inherent fore and aft stability by reducing the centre of pressure movement of the wing; although if the sweepback is overdone, the controls tend to become heavy and slow to react. Sweep back of the wings may be constant throughout the semi-span, that is, a straight back swept spar from the root to the tip, as on the Falcon, or may only be used on the outer part of the wing. The Minimoa is a good example of this, although in this case the wing spar is complicated, and expensive to repair, as it alters direction at the point where the gull finishes, and the effective sweep-back begins.

For the amateur building his first machine the simplest of the above layouts is obviously the straight single-spar high wing, with strut bracing and parallel-taper plan form, with a slight dihedral angle, produced either by inclining the whole wing up from root to tip (*see* Weihe), or, building the wing, which decreases in thickness towards the tips, to a horizontal top surface; this gives a certain amount of effective dihedral, as in the G.B.II.

Wing-Fuselage Joint

The position of the wing, and the juncture with the fuselage, needs careful consideration, as the airflow at this joint must be smooth and without interference; a poor wing-fuselage joint may cause buffeting, and consequent partial loss of control, on the tail unit, as well as lowering an otherwise good performance.

Some designers like to build in an elaborate fillet to smooth out this joint, which in most cases gives the best result if carefully designed. Detachable sheet metal fillets or fairings which are put on after rigging, should be avoided if possible, as they get easily bent out of shape, or damaged, and do not usually fit well after the first week or so, and the final result may then be worse than having no fillet at all. The alternative, and one to which many designers are now inclining, is to go to the other extreme and not have any fillet, depending on careful design to achieve the same end. A general rule on all such joints is that the angle between the two components should be nearly a right angle, and that nearby fittings, such as cockpit covers, should be designed so that there is no possibility of the airflow being disturbed and building up into the join. The Weihe is a good example of the absolutely plain joint between wing and fuselage.

Wing Loading and Area

In addition to loading and area, the characteristics of the wing are also affected by the wing section, which will affect in turn the final loading figure. For instance, the wing area could be less with a very high-lift slow section than with a high-speed section, if slow flying and mild stalling properties are desired. A few notes on Sections follow later.

The amateur designer should always be sure that he has sufficient wing area for the job. It is easy to cut down the wing both to save weight and to increase cruising speed, but the resultant higher loading may bring with it difficult, or unpleasant, flying characteristics at the slow flying end of the scale. A good speed range should be obtained by care and refinement in design, and not at the expense of safety.

In trainers, and general purpose sailplanes, it is advisable to keep the wing loading as low as possible consistent with suitable performance and a handy sized wing; although the experienced pilot may desire a high loading in order to obtain a high cruising speed.

Knowledge of the country over which the machine is to be generally flown produces a need to stick to a fairly standard set of loadings as a general rule. In the U.S. designers tend to use a higher loading and stalling speed than either Britain or Germany. They can afford to do this due to the greater frequency of large landing fields and a higher average cumulus cloud base, which reduces to a certain extent the amount of manœuvering for lift near the ground. In this country, where distances between any point and the sea are not great, average cloud base is low, and fields are often small and uneven, it is wiser to keep the wing loading down, so that the machine is easy and pleasant to handle near the ground, and for landing in restricted spaces. This will be to the detriment of the desired high cruising speed, however.

In the U.S., Utility, or training gliders, may have a loading as high as $3\frac{1}{2}$–4 lbs. per square foot, and high-performance sailplanes and advanced two-seaters as much as 5 lbs. per square foot. In this country, trainers do not usually have a wing loading exceeding $2\frac{1}{2}$–3 lbs. per square foot, and high-performance sailplanes a wing loading exceeding 3–4 lbs. per square foot.

The average wing area and loaded weight of modern high-performance sailplanes are about 190 square feet and 630 lbs. respectively.

Of course, some sailplanes have been built varying widely from these figures.

Wing Section

The wing section should be carefully chosen, as the right section will make all the difference between a really good

machine and an inferior one. There are many sections available to choose from, the characteristics of which are well known.

For trainers, a high-lift slow-speed section should be used, as high speeds are not necessary but good slow flying characteristics are. High-lift sections are usually quite thick, which automatically gives a good spar depth.

On medium-performance sailplanes, if the wing is strut braced, a thinner section may be used which will help cut down air resistance, and the drag saved may more than compensate for that of the struts.

For high-speed sailplanes the choice is more difficult, as, if the wing is to be cantilever for lowest possible drag it will need a good spar depth unless a metal spar is used, and this means a fairly deep section. Some high-speed sections have a tendency to stall sharply or without warning, and so a compromise is usually made; a high-speed section being used from the wing root outwards, which gradually changes toward the tip to a section of slower speed, but better lifting properties, which improves the handling characteristics. The stall then starts at the centre of the wing and spreads outwards, instead of the tips stalling first; this gives the pilot better warning, as the sailplane will start "mushing" along on an even keel, instead of dropping a wing suddenly. In this class of sailplane the wing cannot be too carefully designed if good results are wanted.

Diagram 34 illustrates some sailplane sections.

Wing Construction

The method of construction of the wing and material to be used will need to be decided at this point. In this country, wood is almost universally employed, and certainly is cheaper and easier to build with, lending itself to ease of repair without special equipment. In the U.S., however, there is a tendency towards metal sailplanes, made either of built-up sections, or of welded tube, or both. For the amateur, wood is undoubtedly the better material at the present time.

The two most widely used types of wing construction are the two-spar internally and externally braced wing, and the single-spar cantilever or externally braced wing, with a stiff torsion box leading edge to take the place of internal bracing.

For the trainer, or low-performance machine of relatively small span the two-spar wing is the better, because of its

SOME TYPICAL WING SECTIONS

GOTTINGEN 535

A very good general purpose section for training machines when high speed is not required It combines good lifting with safe handling properties, but is definitely a slow section Used on G B II, Kirby Kite, etc It has a large Centre of Pressure movement

GOTTINGEN 549

A section providing quite good lifting properties with low drag and good handling qualities Useful for medium-high-performance sailplanes for general soaring Used on Weihe, Wien and Meise Large C of P. movement

GOTTINGEN 652

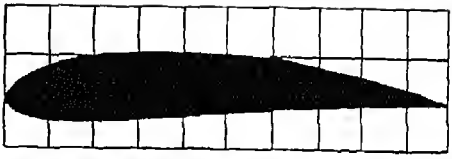
A high-lift section with pleasant flying qualities and gentle stall It suffers from high drag, which increases rapidly with increased angle of attack A good section if a slow machine with low rate of sink is required, but useless for high-speed soaring Used on Rhonadler, Fafnir, and Austria

N.A.C.A. 4412

A fast section with good all-round performance Suitable for high-speed cross-country work, but fairly rapid stall, and little depth for main spar Only slight C P movement

N.A.C.A. 4415

Very useful all-round performance High lift combined with quite low drag, but a much faster section than 535 Suitable for cross-country soaring on medium-high-performance sailplane Slight C P movement



N.A.C.A. 4418

A high-lift section with safe stalling characteristics, but not much use where high-speed range is required, due to fairly high drag

CLARK YH

A fairly low drag section providing moderate lifting properties Due to reflex trailing edge there is little C P movement Quite suitable as wing-tip section

R.A.F. 30

A symmetrical section useful for tailplanes and wing tips, when the section is changed along the span in order to counteract any wing dropping tendencies It is a fairly low drag section, providing moderate lift The C P is stationary

Diagram 34

simplicity both of manufacture and repair. As this type does not need a good speed range the struts, or some wire bracing does not affect the performance to any extent. The spars themselves are usually prepared solid planks with little or no taper in depth, set on edge, with the ribs threaded on like beads, and the whole stiffened with simple diagonal ply members. The wing is generally fabric covered, although the leading edge is often faced with thin ply to add rigidity and to ensure a better entry to the airflow.

The single-spar wing which is used extensively on sailplanes may be cantilever, or braced by a single strut; the necessity for bracing depending on the depth, and design of, the spar and root fittings. In either case the spar is a built-up structure, usually a box formed from solid, or laminated, spruce top and bottom members faced with plywood sides. The root of the spar where the main fittings are attached is usually built up solid, as are other points for strut fittings, etc. The spar also tapers in depth toward the tip, and needs to be built with great care. On to the front face of the spar are fixed the nose ribs, which are little more than formers for the plywood which is then laid over them and attached to the top and bottom of the main spar, this forms a very stiff structure which takes the twisting loads of the wing, as well as forming a smooth strong leading edge. To the back of the spar are fitted the wing ribs, or rather the rear portion of them, and the ailerons, which may additionally be attached to a false light rear spar. This afterpart of the wing is usually fabric covered, except near the wing root where it is ply covered for extra strength, over a short drag spar running from the main spar back to the rear wing-fuselage attachment points (Fig. 73).

The Fuselage

It is necessary to remember that in itself, the orthodox fuselage contributes nothing to the aerodynamic efficiency of the machine. Its object is to carry the pilot, the landing gear, wings and the tail unit, and that is all; therefore it should be as light, clean, and simple as possible. The length of fuselage determines the size of the tail control surfaces; the shorter the fuselage the larger these must be and vice versa. Care should be taken to make this compromise suitable for the job in hand, and to ensure that the proportions also 'look' right.

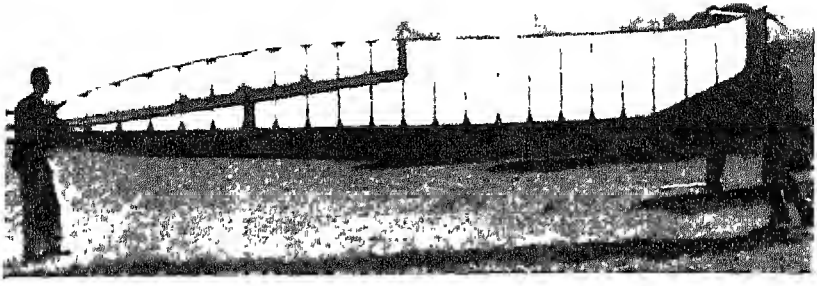


Fig. 73. *Wing of Kirby Kite. Note ply-covered leading edge, root and drag spar position, also ply biscuits at rib-spar attachment points, etc.*

It is almost impossible to get a really smooth section, or surface, with a metal fuselage unless it is covered with metal sheet, which adds considerably to the weight. If, however, the fuselage is built of wood and ply covered, not only can much of the strength be in this covering, but the fuselage can either be hexagonal or polygonal, when it will be very simple to build and repair, or monocoque, which will give the smoothest section, or outline, possible (Diag. 35).

Steel tube construction has some advantages over wood for the fuselage, and also some disadvantages. In event of a crash, the structure is more likely to bend and absorb the force of the impact, whereas the wood fuselage smashes into splinters. On the other hand the damage to the wood fuselage remains local and is easier to repair, whereas damage may be found in the metal fuselage far from the part directly affected by the crash.

The slabsided or the polygonal wood fuselage is easier than the monocoque to construct and repair, and is also lighter,

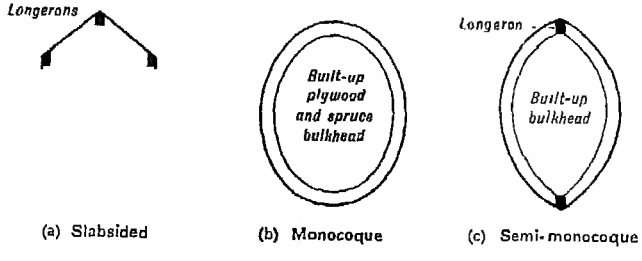


Diagram 35

being a simple straight-forward skeleton built up of strips of wood, and covered with flat panels of plywood.

The wooden monocoque, on the other hand, although heavier and more complicated, considerably improves the streamlining of the machine, and lends itself to a finer surface finish. It consists of strong built-up bulkheads of the exact fuselage section: these are positioned with stringers and the whole is covered with plywood panels. A complication exists in that each ply panel is, of course, curved, and on the nose especially it is difficult to avoid double curvature of the panels. Instead the ply is usually put on in small strips or pieces, although this makes both for complications and weight as extra formers have to be built into the nose, so that there is some base upon which to glue these pieces. With regard to the welded steel tube fuselage, work of this type should not be attempted without proper equipment, and adequate previous experience.

Location of Pilot

The usual position of the pilot is forward of the centre of gravity of the aircraft. This position is almost inevitable on a small machine where the weight of the pilot is a large proportion of the total weight, and he is needed to balance the length of fuselage necessary for adequate operation of the orthodox tail unit. It is however a good position, in that there is every opportunity to give him a good view in all directions.

If the pilot's head projects above the wing, some form of strong head guard must be incorporated, in case the machine should turn over on landing. The cockpit should be easy to enter, and fly in. The pilot should not have to have long legs to enable him to step over the side, and then need to have half of them cut off as he cannot get his knees under the instrument panel. He should not have to insert his feet through holes like the stocks, in the forward bulkhead: and, once in he should be comfortable and not get a stiff neck, a strained back or tired arm after thirty minutes' flying. He should have as much room as possible and be able to get out by parachute from any position. If the cockpit is fully enclosed, the hinge fittings should be strong enough to permit of the odd spectator leaning on the hood when in the open position; and the hood should also be fitted with a jettison device for emergency use. A small direct vision, or pull-

out panel, in the screen should be incorporated for bad visibility or icing. The transparent material should not scratch or discolour easily (Fig. 74).

Location of Releases

The position of the quick release, or releases, for the launching cable should be located during the early planning.

Fig. 74. *Location of pilot* (1) *Kirby Kite* (*author*), (2) *Petrel I* (*P. M. Watt*), (3) *Rhonsperber* (*F. T. Gardiner*), (4) *Minimoa* (*P. A. Wills*).

The ideal is to have two releases; one in the nose for the direct pull of an aero tow, and one lower, and nearer the centre of gravity of the machine, for winch launching. This latter release should be very carefully placed, as if it is too close to the C. of G. the machine may become unstable fore and aft, and generally be difficult to control during launching. If the winch release is too near the nose, considerable backward pressure on the stick will be necessary to climb steeply during the launch. Normally, only one release is fitted and this is placed in a compromise position a little lower and farther aft than the ideal for aero-towing, and more forward than the ideal for winch-launching.

The difference that this compromise usually makes, is that the machine may be a little heavy on the elevators, and require the nose to be held down continuously on an aero tow, while needing to be held back more on a winch launch.

On sailplanes, the release is usually fully buried in the fuselage so as not to cause drag; this means that the ring of the launching cable may have to be pushed into a tunnel before connecting with the jaws of the release. Care should be taken to see that the length of this tunnel is as short as possible, and that the mouth is smooth, and protected, so that any danger of the ring jamming, or catching, is eliminated. Every care should also be taken to make the release accessible for maintenance without someone of special shape having to be procured to turn himself inside out down the fuselage, to clean, or oil it.

On trainers, where low drag is not so important, the release can be externally fitted. This greatly facilitates maintenance but limits the position, as it may get jammed or damaged by stones or long grass, if placed too near the ground.

Skid Fittings

Very close to the usual position of the release, will be the nose fitting of the skid: this too, must be easily accessible, and neither of these two fittings should necessitate the removal of the other before they can be worked on.

On trainers the skid nose-fitting should be simple, as often the skid may be split, or torn off, without any other damage being incurred, so the quicker it can be replaced the better. A single nut and bolt through a metal-bushed block on the

skid and in the nose of the machine will be found to give satisfactory results.

The main skid fitting usually consists of a hard rubber block, or ring, fitted into a sheet metal holder which is bolted to the skid, and attached by a leather or metal strap to the base of the main fuselage bulkhead. This may appear weak, but it is amply strong for all but bad drift landings, when it is infinitely preferable for the skid to go, breaking either the rubber block or the strap, than for the fuselage itself to be damaged, or the main wing fuselage fittings wrenched, or strained.

Landing Wheel

Some sailplanes have a single low-pressure landing wheel fitted under the main bulkhead, using only a short nose skid, forward of, and of less depth than, the wheel. This wheel increases maintenance, weight, and to a very slight extent drag, but its benefits are infinitely worth while. It prevents the vibration, and shaking, which the whole machine receives when landing on, or being retrieved over, rough ground. If transport is not available the machine can be pulled along backwards by two people for short distances, instead of having to be dragged or carried by at least three (Fig. 75).

At the same time a light and simple brake can be fitted for parking purposes, and to assist in landing.

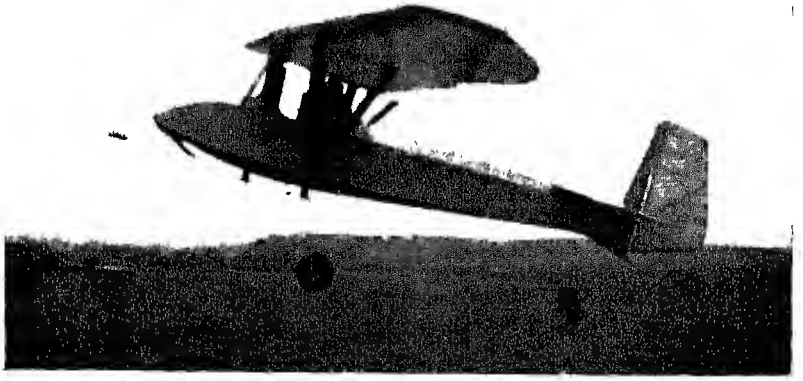


Fig. 75. *Falcon III two-seater jettisoning the pair of detachable wheels used to assist take-off.*

Unless absolute cheapness and simplicity are required, the wheel is an advantage to all gliders and sailplanes, including elementary trainers.

Tail Skid

The tail skid can either be a solid built up extension of the fuselage itself, shoed with steel strip, or can be of the spoon variety, bolted to the rear bulkhead. The former is better where a monocoque fuselage is used, and the latter type for trainers.

The Tail Unit

The tail plane may be either fixed with movable elevators, or of the pendulum or balanced type. The former is more usual practice at the present time; the advantages are that it can be easily externally braced, thereby simplifying construction, and it is more stable in flight. This is better for the pupil who does not want a machine which jumps all over the place: if he is a bit heavy handed, or inclined to "pumphandle". Most pilots also prefer the fixed tail plane if contemplating blind-flying and continuous circling in clouds.

The pendulum type, in which the whole tail plane and elevator is one movable piece, hinged just aft of the leading edge, is very light to handle; it is also lighter to build, and preferable if instantaneous control is required by a light-handed pilot. The pendulum type was used extensively on sailplanes in Germany and elsewhere in the 1930's, but has given way since to the more orthodox fixed type.

The rudder can be either built with a fixed fin forward, or fully movable and balanced. A usual fault with amateur layouts is to design too small a rudder, giving inadequate control at low speeds, and for quick recovery from a spin.

Both the elevator and rudder, whether of the fixed or pendulum types, may be balanced if necessary, by having a percentage of their area forward of the hinge line (*see* illus. chapter 9, Falcon, G.B.II, etc.), or by fitting a streamline lead balance weight in a similar position.

The orthodox construction of the whole tail unit is very straightforward, usually consisting of simple riblets attached to light solid spars, and fabric covered; except for the leading edge, or nose, which is usually of ply.

On sailplanes which may have to be flown for some hours at a stretch, it is advisable to fit a trimming tab to the elevator so that the load on the stick may be adjusted in flight. One method of doing this is to make a small length of the elevator trailing edge adjustable, like a minute second elevator; this is operated in the reverse direction to the main elevator, that is, when the tab is raised the pressure of the airflow over it increases, and causes the main elevator to be depressed slightly, thus decreasing any backward load on the stick, and permitting it to be held forward more easily. A very simple method, which is however only useful if it is not required to adjust the elevators while actually in the air, is to attach, by screws, a small piece of aluminium sheet about 4 inches by 2 inches on to, and extending to the rear of, the elevator, and bending it up or down the estimated amount before take off. This is particularly useful when a sailplane is owned by pilots of widely different weights.

Ease of Rigging

If the machine is to be dismantled in between flights, attention should be given to the ease and speed with which rigging, and de-rigging can be done.

Small detachable parts such as little fillets, or fairings should be reduced to the minimum, and all attachment points should be readily accessible: it is most aggravating to have one's knuckles skinned every time the elevator is connected.

A simple form of attachment uses a straight, or slightly tapered, mild steel pin, and safety pin (in preference to a split pin); although split pins should be used for the moving links in the control system.

Some designers incorporate connexions for the controls, which automatically lock when the main fittings are brought together, *i.e.* the elevator control connects itself when the tail-plane is bolted on. This is a pleasant refinement, but is not necessary, if the ordinary fittings are well made and kept greased. For instance, a G.B.II, which has no automatic attachments can be rigged or dismantled in 8-10 minutes by two people.

The job of rigging will, however, be made easier, if the connexion is such that it is possible to lower one wing tip to the ground after partial attachment, instead of needing to support it, until both wings are locked in place.

Spoilers, Airbrakes and Flaps

Spoilers are fitted to high-performance sailplanes possessing a flat angle of glide and a tendency to build up speed rapidly, to enable the glide to be steepened without increase of speed when coming in to land. Airbrakes additionally limit the terminal velocity of the machine to a maximum safe speed in case of difficulties when cloud flying. Flaps, either of the split or plain variety, are sometimes used, but these may be too heavy for ordinary use as they require a strong trailing edge, with the probable addition of a rear spar.

Fig. 76. *Gull I coming in to land with lift spoilers raised.*

The simple lift spoiler is the most widely used and is cheap and light to build, although it loses its effect and may even become inoperative at extremely high speeds (Fig. 76). It consists of two metal plates about 2 ft. long and 6 ins. wide, located on top of the wings and hinged at their forward edge, just behind the main spar. They are placed so that their sphere of influence is outboard of the tail plane and inboard of the ailerons: when in use, the metal plates are raised against the air flow, causing the lift over an increasing area of the wing behind them to be destroyed. This requires that the nose of the machine shall be lowered in order to maintain the existing speed.

As the plates are thin and flat, they can lie on the top surface of the wing, and do not really require to be inset unless a very high performance is required from the machine.

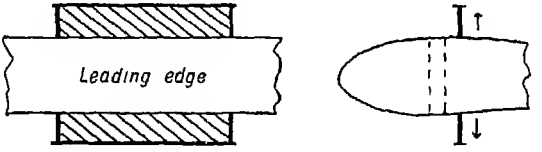
The airbrake (or dive brake) consists of two similar sized plates, which instead of lying flat, and being hinged at the forward edge, are buried within each wing on edge, and are pushed upwards and downwards in this position. This is a very effective lift spoiler and can be designed to limit the terminal velocity as mentioned before. It is, however, less simple to build, as it needs additional strength to stand up to the higher speeds to which it will be subjected.

A very simple type of spoiler sometimes used on solo primary training machines, to prevent them leaving the ground or being suddenly gusted up in rough weather, consisted of two long flat panels which are fitted along the leading edges of the wing at right angles to the chord. As they are only temporarily used, they are usually just tied on with tapes or clips (Diag. 36A, b, c, and a, respectively).

A catch should be fitted to enable spoilers to be locked "out" on the ground. This lessens the risk of the glider blowing over on the ground.

(a) Detachable spoiler for ground slides

(b) Simple lift spoiler



(c) Dive-brake spoiler

Diagram 36A

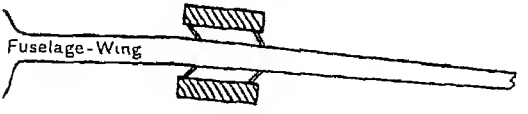


Diagram 36B. *Dive brakes, similar in principle to those fitted on Weihe.*

Cockpit Layout

When dealing with the layout of the fuselage, the actual shape of the cockpit and position and view of the pilot was planned. Now we come to the detailed layout of the cockpit interior. Firstly, the instrument panel should not be so close to the pilot that he has to re-focus his eyes whenever he wishes to read the dials, nor should it be so far away that there will be any strain attached to seeing any figures or adjusting the instruments by hand. When the Sutton type safety harness (which should be fitted) is properly adjusted, there should not be danger of the pilot's head being swung forward on to the panel in event of a crash. If there is, the panel should not be so rigidly fixed that it is likely to become the immovable object, or, if this is not possible due to the fuselage shape, then it should be thoroughly padded by leather covered sorbo rubber. A large amount of minor, and sometimes major, damage has been unnecessarily caused to pilots through lack of attention to this point.

The instruments on the panel should be grouped in an orderly way, so that the eye reads them naturally. A suitable arrangement for the most frequently used sailplane instruments would be, Air Speed Indicator on the left, turn and bank in the centre, with other blind-flying instruments above or below it if they are fitted, and altimeter on the right. The variometer should be between the A.S.I. and the turn and bank, but a little above them. This arrangement makes it easy to see the variometer and A.S.I., together for ordinary soaring, but does not interfere with the straightforward reading of the A.S.I., turn and bank, and altimeter when blind flying. (Diag. 37).

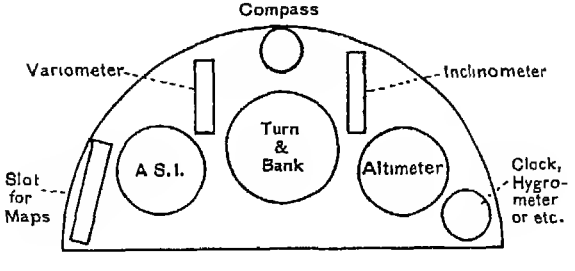


Diagram 37

Extra instruments such as clocks, hygrometers, etc., should be placed on the extreme right of the panel.

The location and the amount of pigeon holes, pockets and holders, should be planned at this stage, and it should be stressed that it is almost impossible to provide too many, especially if long flights are hoped for. This point will be appreciated by those pilots whose entire food supply for a duration flight can be heard bouncing about in the depths of the fuselage, or whose map can be only viewed dimly beyond their feet at a difficult point on a distance flight.

If there is room, maps can be pushed into a deep slot on the extreme left of the instrument panel, where they can be reached without moving one's eyes from the variometer. Map pockets with zips are not very good in practice, as the edge of the map may catch in the opened zip and either stick, or deposit a few linen threads in the zip teeth so that it will not do up the next time.

At least two other pockets or pigeon holes should be fitted for food, gloves, dark glasses, odd handkerchiefs, and/or other sundries; it is extraordinary how inaccessible one's own pockets become when flattened beneath both parachute and safety harness.

Location of Auxiliary Controls

Next on the list is the location of the auxiliary levers, for flaps or spoilers, wheel brake, quick releases and any other gadgets which may be fitted. The best position for the quick release control is undoubtedly the bottom left-hand corner of the instrument panel, it should consist of a ring big enough for the insertion, and extraction, of a gloved finger, and yet not be so thin that a good tug practically severs a bare finger, or, it should be of T-shape and big enough to be easily grasped.

Both the flap or spoiler lever, and the wheel brake lever should be located on the left, near or on, the floor, as the most natural way of bringing these two auxiliaries into use is by a backward and upward pull. Both should be manually operated for lightness and simplicity, as the loads are not great. The brake lever should have no automatic catch either going forward or back, but should be fitted with a simple manually operated catch for parking. If the two levers are to be close together, they should

be of different shape and size so that it is not possible to mistake them by feel.

As regards lining and general comfort, the cockpit of the sailplane should be made as comfortable and draughtproof as possible, and this may be done with very little increase in weight. Two-seaters, especially those used for joy-riding, should appear secure and well finished: people have turned away from gliding in the past after just looking into a cockpit, and seeing the "works" in all their apparent frailty.

With regard to trainers, the comfort question can be overdone, the pupil should be surrounded by a fairly rugged but plain structure, although a simple padded seat will do no harm! Especially when his confidence begins to grow rapidly, the pupil needs to be reminded of the lightness, and simplicity, of his craft, and not be surrounded with false security.

To finish this chapter it must be said that it has only been possible to go quickly through the general layout of the orthodox machine. There are, however, distinct possibilities for the development of tailless, or tail first, sailplanes, or even all-wing designs, but these have many problems of their own.

Chapter 11

TOOLS, MATERIALS, JIGS, BUILDING AND REPAIRS

Materials for Sailplane Construction

The two most used classes of material at present are (*a*) Wood, using a built-up structure of spruce, or other similar timber, and plywood, with coverings either of fabric or stressed ply sheet, and, (*b*) Metal; the machine being built up of metal strip and sheet, or welded tubular members, covered with fabric or thin alloy sheet.

A third class of material which may become widely used for sailplanes in the future is plastics; although moulded plastic-bonded plywood produced as prefabricated rear fuselages, or unit fuselage noses complete with cockpit fittings may well be the first items to which this developing class of materials will be put. It is, however, expensive when only a few machines of the same type are to be built, owing to the machines tools, jigs, and autoclaves, etc., necessary. The cost decreases the larger the quantity to be made of any one machine: plastics are eminently suited to mass production, and at the present time civil sporting gliders and sailplanes are not.

The following are a few brief notes on the more frequently used constructional materials.

Woods — *Plywood*

Plywood is produced in two grades suitable for sailplane work. Grade 1, which is used for stressed parts, and in which birch, mahogany, or satin walnut, should be used for at least the two outer plys, and preferably all three. Grade 2 is used for unstressed parts and fairings, and ash may also be used or the outer plys. The middle ply in either grade may consist of lime, poplar, willow, alder, or American white wood. Of these plywoods, birch and mahogany are the most widely used. Plyboards are supplied in different thicknesses, $1\frac{1}{2}$ mm. and 2 mm. boards being most widely used for gliders. During the War the Germans used beech ply for many stressed parts.

There should be no shakes, or filling, in the wood, or rot or deterioration of any sort. The grain of the outer plys should

run the length of the board or panel, with the middle ply grain at right angles. Some ply boards have the outer plys laid diagonally for torsional strength, and are occasionally used for the leading edges of wings, etc.

Ply boards used for sailplane work should have as few joins as possible, and one face should be free of them.

When the separate plys are originally cemented together, they should remain flat, and develop no blisters or wrinkles; the cement should not be affected by damp or moisture, or by varying temperatures and changing weather.

The two outer plys should be of equal thickness, and the middle ply as thick as a single outer ply, but not as thick as both the outer plys together.

Each plyboard when it is purchased should be stamped with the name of the woods used, and with other data such as date of manufacture.

Most of the usual tests of plywood can be done quite simply if these are thought necessary. The test for adhesion requires that forcibly separated plys should show wood fibres. The Dryness test requires that a 2-inch square specimen should show a loss in weight of 8/18 per cent after being dried in a 221°F. oven for ten hours. A test piece of plywood should show no signs of separation after having been boiled in water, either while still wet, or when subsequently redried.

Spruce

Spruce is the most widely used wood in sailplane construction, and largely comes from British Columbia.

In the planks used for aircraft there should be no dote (brown spots), shakes or compression shakes, or knots, other than very few pin knots or resin pockets. The grain of the wood should run parallel to the plank, if possible, and certainly should not diverge from it by an angle of more than 1 in 15. The spiral grain limit is also 1 in 15, and this spiral is caused by twisting in the growing tree.

The annular rings should not be less than eighteen in any 3 inches.

When purchased the timber should weigh not less than 25 lbs. cubic foot, and there should be at least 12 feet clear of knots, and no blue or damp marks should be visible. Aircraft quality spruce is always stamped.

Ash

Ash is used in sailplanes for hardwood blocks, and landing skids.

Wood obtained for sailplane use should not contain any knots, shakes, curly grain, burrs, caney end grain, black heart or rot, and at least half of each annular ring, of which there should be four to the inch, ought to show close autumn wood. If the wood is to be used for parts where it will be steam bent it should preferably not be seasoned, nor kiln dried. Ash should not weigh less than 38 lbs. cubic foot, and the maximum inclination of the grain from straight should not be more than 1 in 12; although curved parts should be cut from naturally curved grain.

Balsa Wood

Balsa wood weighs very little, but also has little strength. It is used for fairings and fillets, and will take quite a good final surface if an adequate filler is used before painting or varnishing. It is very easy to cut and shape.

Mild Steel

The main use for mild steel is for fittings and connections. It is lighter, and easier to work than high tensile or stainless steel, although not so strong.

Mild steel is obtained in the form of bars, sheets, tubes, forgings, and stampings. The bars are used for such items as low tensile nuts and bolts, and small fittings. They may be reheated to a maximum of 620°C before or after cold working. Sheet steel is used for plates, and fittings. Tubes are used mostly for struts, either of circular or streamlined shape. These tubes are seamless, and usually cold drawn, after which they are heated to 350-480°C. for blueing, and then cooled in still air. After welding, fittings must be normalised. Bent or pressed fittings should be tempered at 450-550°C. and cooled in still air.

The most usual defects in mild steel are cracks, seams, draw marks due to dirt in the dies, faults due to flashes of metal being pressed or worked in, during subsequent rolling. Piping, and cracks issuing from the inspector's stamp. Blisters, buckling and laminations, are other defects which occur in mild steel sheet.

High-Tensile Steels

These are used for such fittings as require to be especially strong. They are used only infrequently in normal sailplane design, unless the construction is to be of welded steel tube. They are alloy steels containing nickel, tungsten, manganese, molybdenum, and a certain percentage of chromium. Stainless steels have a high chromium content, but are not absolutely free from corrosion. Case hardened steels contain about 3-5 per cent nickel.

High-tensile steels are usually supplied in a fully heat treated or annealed condition, to be later hardened or tempered.

High-tensile steel bolts have nicks round the head and on the nut to distinguish them.

Aluminium

Aluminium is used for fairings, and cowlings, or other non-stressed metal parts; it is light, being only one-third of the weight of steel.

It can be obtained in three grades. Hard: with a tensile strength of not less than 9 tons per square inch. Medium: of 7 tons per square inch, and Soft: of 5 tons per square inch. All these grades contain 98 per cent pure aluminium.

The usual defects in aluminium are blisters, buckling, lamination, dirtspecks, laps, and chromic stain after anodising.

Aluminium rivets have a dent in the head for recognition purposes.

Alclad is duralumin sheet covered on both sides with aluminium.

Duralumin

Duralumin is aluminium with copper, manganese and magnesium added. It is very slightly heavier than aluminium, but is considerably stronger in tension, although sheets will not stand up to reverse bending.

Dopes

Dopes are used to make the fabric covering of wings, etc., both taut and weatherproof.

Clear dopes contain a large proportion of cellulose acetate and acetone, and lesser quantities of methyl ethyl ketone, alcohol, benzol, benzyl alcohol, and triphanyl phosphate.

A test film of the dope should be clear of whiteness, and removable without tearing, when dry.

Doping should be done in a warm, dry, draught-proof room; and the dope itself should be kept stirred.

When not in use dope should be kept in an airtight tin.

Flexible Steel Cable

This is used for control cables, bracing wires, and also for winch launching and aero-towing.

Unless the cable is made of stainless steel strands, it will be coated with hot galvanising before final drawing.

The cables in general use for sailplane purposes are as follows:

(1) 5 cwt. Used for auxiliary controls, such as quick-release cables and weak links; this contains seven strands of seven wires ·08 inch diameter.
(2) 10 cwt. Seven strands of fourteen wires ·12 inch diameter.
(3) 15 cwt. Seven strands of nineteen wires ·15 inch diameter.
(4) 20 cwt. Seven strands of nineteen wires ·16 inch diameter.

The 20-cwt. cable is not often used except for basic training launches, where a strong cable is needed and its weight is not important. Ten and 15 cwt. cable are most generally used for control cables, bracing wires, and launching purposes.

Cable should be tested for kinking, and slack, crossed, or missing wires, or strands.

Cable used for winch launching should be spliced at the ring attachment, but may be tied with a suitable knot at breaks. Cable for control purposes and bracing wires should be always properly spliced, conforming to the following: there should be a minimum of four-and-a-half tucks; serving should only cover base ends of wires and half tuck; no light should show through the splice, and the ends should be properly secured.

An eyelet should be used to prevent wear inside cable loop, and this should fit well. A bad splice will loosen if frequently bent.

Casein Glue

Casein glue which is derived from milk, should be freshly mixed for each separate job and should never be used after it is 3½-4 hours old, or until it has been mixed for twenty minutes. The glue powder should be taken direct from the tin, *added to* cold water and mixed to a medium-thick cream. No more

powder should be added once the mixing has been started. The proportion should be five parts of water to four of glue.

Casein glue has now been almost superseded by a range of synthetic glues.

Tools and Jigs

This section has been written for the amateur who will want to build, and repair his machine with as little initial outlay as possible, and who will not want to acquire equipment for quantity or production work.

The first requirements are: A good large bench, or solid table, with a vice attached.

Rip saw: this need not be large unless timber is bought in large planks. Hack saw.

Various rasps and files. Three chisels between $\frac{1}{2}$-$1\frac{1}{4}$ inch wide.

Smoothing plane, and if desired, one of the small metal variety, or a small spokeshave, if this tool is liked.

A square; sand and emery paper.

1-lb. hammer, and a tack hammer.

Drills, and assorted bits for both wood and metal use.

1 pair of good tin shears. Sharp knife. 3-foot steel rule, large and small screwdrivers, pliers, oilstones.

Adjustable and suitable (2-B.A. and $\frac{1}{4}$-inch B.S.F.) fixed spanners, small punch, and cold chisel.

As many cramps, or clamps, as it is possible to obtain, and if possible, lengths of bungey, or rubber strands.

The need for other tools, and makeshifts, will appear as work proceeds, as each person has his own way of doing things. Also, an assortment of jars, bottles, shelves, boxes, tables, and wall hooks will be found inevitable.

Proper lighting and adequate space are obvious necessities.

Glue, dope, paint, and varnish and the various brushes and containers to be used with them.

Jigs

Jigs are required for building up certain parts of the machine; a large one will be required on the floor for setting up the fuselage bulkheads, and others will be required on boards and tables, for building the bulkheads themselves, the wing ribs, and the tail unit parts. Another large one will be required on the floor for the actual wing assembly.

A simple way to cope with this pre-construction work is to build up a rigid but temporary structure attached directly to the floor, or in the case of smaller components, to thick boards.

If possible, it is an advantage to have several of these jigs available at the same time, and then work need never be held up while glue is drying.

When making the smaller jigs it will be found that work is reduced by drawing the actual part to be made direct out on a large heavy board, and screwing on sufficient small blocks of wood to keep the pieces of the component in their exact position prior to and during the process of glueing. Do not put the spacing blocks where any cramps will subsequently need to be used. If there is danger of glue running out of the joint and sticking the component and the jig together, lay scraps of newspaper in between.

All biscuits or plywood stiffeners should be glued to the visible side of the component before it is lifted from the jig. This will fix the shape sufficiently for the whole thing to be lifted out, and the biscuits or ply facing glued to the other side.

It is an advantage to keep the jigs for subsequent use in case it is desired to make further similar machines, or in case extensive repairs are required, but if boards and space are short the blocks can be unscrewed and a new jig made up on the same board.

The fuselage jig is constructed so that the fuselage is built inverted, that is, the top longeron (if the fuselage is of the slab-sided type) is the base line upon which the rest of the fuselage is built up. This jig can be made of heavy pieces of timber, nailed or screwed direct to the floor, and is best devised in detail by the constructor of the machine. The first essential is that each bulkhead shall be set up true and rigid, so that the longerons can be fitted into their respective slots and glued up without causing any distortion or twist of the fuselage as a whole.

The jig for the wing needs to be very accurately built, as it must hold the spar so that the leading edge ply can be glued on over the nose ribs without introducing any twist.

Building

It may sound an obvious thing to say, but when starting on any job of aircraft construction it is more than usually

essential to have all tools, etc., ready, and a plan of work clear in one's mind, as well as possessing a thorough knowledge of the drawings, which must be complete and accurate.

It is wise, however, to start building some simple part, such as the rudder; and with the drawings to hand, the jigs made and materials ready, it is surprising how soon such a part will be finished. It is necessary, however, to stress here that only absolute accuracy is good enough in aircraft work, and even the smallest error in cutting or fitting may result in an alteration of strength, or flying qualities, in a machine. Even mass produced aircraft built in streams off the same true and expert built jigs often vary one from the next as regards performance and handling qualities. If there is the slightest doubt that any part is not quite right, or that any joint is relying for its strength upon being filled up with glue, that part should be remade while it is still easy to get at. If not, it will have to be done later, as it will not escape the inspector's eye when the machine is being checked for Certificate of Airworthiness. If the machine is to be flown in countries where there is no inspection organisation available, then it is more important than ever that the constructor shall be absolutely honest with himself, and ruthless in scrapping any parts which are not perfect. As each component is finished to the extent that it can be lifted from its jig, it should be tested once again for trueness, painted all over with a thin coat of Shellac, and allowed to dry thoroughly before having metal fittings attached. It should not be covered with fabric, but hung up in a dry place so that it will not become damaged or warped.

The tailplane and elevator are the next best parts to build and may be constructed as one component and then cut apart at the hinge line afterwards, or built as two separate items, depending on the design.

While these two components are being constructed, work can proceed on the wing ribs. There will be many of these to make, and unless they are interspersed with other work, their construction will become boring in the extreme.

The amateur's first machine will most likely be designed so that at least part of the wings are of parallel chord, so that a good many of the ribs can be made on the same jig. When these are finished, by which time the constructor will almost be able to make them with his eyes shut, it will pay him to build six

to twelve extra ones in case of subsequent breakage of the machine.

The fuselage bulkheads are next to be built and the small and simple ones near the tail should be made first. Monocoque bulkheads are more complicated than those of the slab-sided or hexagonal fuselage, so it is probable that the amateur will have chosen a fuselage of the latter type. The main bulkhead with its root or strut fittings should follow.

All the original timber in the bulkheads and ribs should be used in unjointed lengths and any ply facing should be made from one piece.

When all the fuselage components such as bulkheads, stern post, and such cockpit parts as are fitted to the bulkheads are completed, work can start on assembly.

As stated previously, the bulkheads are firmly fixed into their exact position in the jig, and the fitting and glueing of the longerons is commenced. In order to keep the work true, longerons (and subsequently ply panels) should be put on in pairs for example, left top, right top, left bottom, right bottom, and so on, and the whole checked for alignment with each operation.

The spruce strips for longerons will probably need jointing somewhere along their length, and these joints should occur at a quarter, and never more than a third, of the distance between bulkheads, and consist of a scarf joint, the angle of which is at least 1 in 9.

When the longerons, and any suitable cockpit fittings are completed, the bottom and sides of the fuselage should be covered with ply. The panels should be cut so that they just overlap the top and bottom longerons (excess being trimmed away afterwards) and long enough to cover the overall length between two or more bulkheads.

Ply joints should be scarfed with a joint of 1 in 9 and all scarfs should occur on the bulkheads, and never between. Panelling should commence at the tail and work forward so that the lap in the ply does not face the air-stream. While the glue is drying on the ply joint, the scarf should be held firmly closed by numerous cramps on bearing, or packing, strips, or where this is not possible, by the use of strip wood tacked along the joint with brass brads. These should be removed afterwards, and no brads used in joins, the glue by itself being strong enough.

If any of the panels are to be fitted with inspection holes and covers these should be inserted before the ply is fixed in place. When the side and bottom panelling has been completed, the fuselage becomes a rigid structure, so after the attachment of the landing skid, and wheel if fitted, the whole thing can be lifted from the jig and set the right way up. Before the top ply is glued in place, everything that needs building inside the fuselage should be inserted, such as the control cables, and stick and rudder assembly. These should be operated fully in order to see that there is no chafing of the cables at any point, even when they are slacker than need be. It will be worth while to finally check that everything has been done that can be done, before the fuselage becomes enclosed.

The whole of the inside of the fuselage should be coated with protective shellac.

At any point where rain water may collect, such as the lowest point of the fuselage immediately forward of each bulkhead, drain holes, about $\frac{3}{16}$th diameter, should be provided, and their edges well shellaced.

The skeleton rudder and tailplane should be temporarily fitted at this stage and checked for alignment. The fuselage top ply is now put on in the same way as the other fuselage panels, and the cockpit fitted up. If any part of the fuselage is to be fabric covered, it should be left open at present.

Now comes the most important and accurate part of the work, the construction of the wings. Not only must these each be absolutely true, but they must match perfectly as well.

The simplest form of wing construction for the amateur is of course the parallel-chord two-spar wing. As mentioned previously, the spars are normally planks set on edge upon which the ribs are strung and positioned. The whole wing is stiffened by diagonal ply webs or wire bracing, the former being the lighter and more satisfactory. This type of wing is not, however, so suitable for a high-performance machine, and the single built-up box spar wing with the ply faced leading edge, is better in this respect, although more difficult to build. If possible, the amateur would be advised to get spars of this type built up by an expert constructor.

The box spar consists of a top and bottom spruce member, which vary in thickness according to the local strength required. This is done by means of glued laminations of increasing length

which are afterwards planed off so that the thickness changes smoothly (Fig. 77). At the root, where the main fittings are attached, the spar is laminated up solid, and this may occur again at such points as aileron fittings, wing tip and point of gull or sweepback in the spar. These top and bottom members

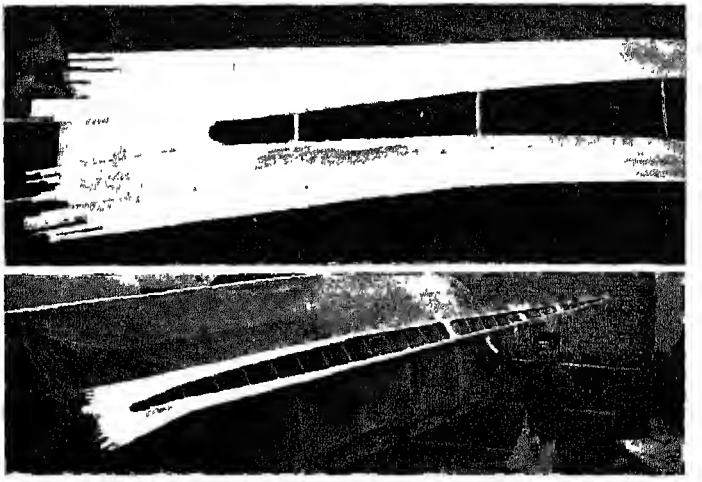


Fig. 77. *Untrimmed main spar of Viking II before being ply faced. Note laminations.*

Fig. 78. *Wing root fittings and root rib of Hjordis.*

are then faced with ply on both sides, ensuring that no twist is accidentally built in; and the whole makes up a rigid structure. The spar ends should be coated well with shellac or bitumastic paint.

The wing root and other metal fittings should now be attached, taking care not to strain the spar (Fig. 78).

The nose ribs should be glued in position, and it is important that all the glue bearing surfaces of the nose ribs should be as well made as possible so that the final torsion box will be at maximum strength. When this is completed the spar should be set up rigidly and absolutely true before the nose ply is glued in place. This is a difficult job which must be done accurately. The ply panels should first be cut to size, allowing a little excess which can be trimmed off after glueing, and scarf faces should be roughly shaped. The panels should then be damped, and carefully bent as for final fitting, until their edges touch, and then bound round with string or rubber strands so that this position is maintained until the panels are dry once more. This will greatly help in positioning, and subsequent glueing.

Panelling should commence at the root and work outwards towards the tip, and the panels should be fitted and glued first to the underneath of the spar, fixed with tacking strip, and bent up over the nose ribs on to the top of the spar, where further tacking strip should hold the whole panel absolutely firm. The contact between ply and nose ribs should be close enough not to need any further temporary fixing, although the panels may be bradded at these parts. Do not put on the next panel until the glue of the first is dry, trimmed, and the scarf for the next panel joint finished, and cleaned up. Check for truth in the spar between the fitting of each panel.

When the nose panelling is complete, the now rigid box structure should be re-jigged in a nose-down position for the fitting of the drag spar and ribs, etc. This should be done with the spar about 18 inches from the floor so that the top of the job (the trailing edge) can be easily reached.

As soon as the drag spar has been fitted and the root ribs have been attached, enough of the trailing edge should be inserted to allow of the ply covering over the root ribs to be glued on. This will make a rigid start against which the alignment of further ribs can be checked.

The aileron is usually built as part of the wing and then cut away along the hinge line afterwards.

The complete trailing edge and any ply covering, or stiffening, at such points as the wing tip, or location of aileron hinges, should be glued into position and the ailerons severed and hinged before the wing is taken from the jig.

Aileron cables should now be inserted, and the wings attached to the fuselage fittings, and propped up so that the controls can be connected and checked from the cockpit.

Any wing struts should be left until last, so that their *exact* length can be checked from the machine itself, to give the right amount of dihedral, if any.

With the whole machine assembled in partial skeleton form, every fitting and moving part should be extensively checked over for accuracy, and every bit of visible internal woodwork should be shellaced. Final attachments such as cockpit cover, and fairings, should be added. The machine should then be weighed and thoroughly cleaned of every particle of wood dust, swarf or other extraneous dirt, and moved to another room, or if this is impossible, covered with dust sheets, while the workshop is cleaned out. At this stage the machine should be inspected for Certificate of Airworthiness.

The attachment and doping of the fabric covering comes next, and it is necessary that the air of the workshop should be dry and warm. The fabric should be put on in as large pieces as are easy to work with, and should overlap the wood bearing surface by at least half inch. First of all, brush the dope thickly on to the wood on which the fabric is to be attached and then press the fabric well into the dope so that it comes through on to the fingers. It is best to start with the leading edge of the fabric panel and stretch taut to the trailing or rear edge of the part concerned, where it is again pressed into the dope. Now pull the fabric outwards over the ribs or formers in a similar manner. These operations can only be done one at a time, so that the dope has time to dry, and will not get pulled slack, or out of place. Wrinkles should not be allowed to form, and the panels themselves should not be doped over until the whole component is completely covered, as this may cause distortion.

Two coats of dope should be given. When the doping is completed, the whole machine should be given two coats of varnish or paint (varnish if the machine is at all inclined to be overweight), and the first coat should be thoroughly rubbed down, first with fine glass paper, and then with a piece of leather, before the second coat is applied. A final and very thin coat of good wax polish and hard work, will make the machine look really professional.

The above is only brief, and general; the detailed information needed for the construction of a machine should be contained in the working drawings for the particular aircraft.

Repairs

Sooner or later, the amateur's fine new machine will probably need some repairs. They may be minor ones caused by someone's foot going through a cockpit panel, or the fitting of a new skid, or smashed panels due to the machine coming adrift in the trailer while on tow; or they may be major ones caused

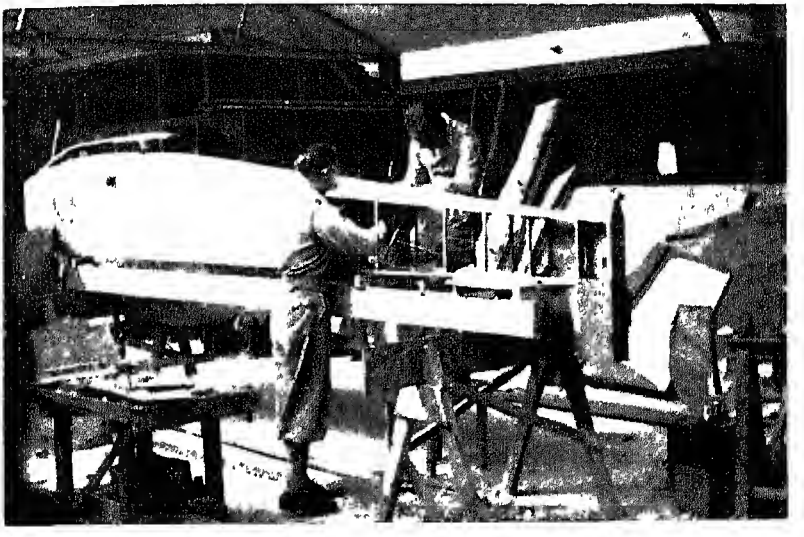


Fig. 79. *Repairing the rear fuselage of G.B.II.*

by the amateur becoming over enthusiastic about the machine's sturdy qualities, or his own piloting. If of the latter type, the amateur will just pack up and take the bits back to his workshop, where he will remember not to splice spars or longerons at points of contraflexion, or to make any scarfs with an angle of less than 1 in 9. He will also check that any new timber he inserts, has the grain running the same way as that of existing parts (Fig. 79).

If, however, repairs are of the minor type and he wants to continue flying, a different technique must be used.

So-called field repairs are of two types, temporary and permanent. On aircraft, obviously there are not many parts to which a temporary repair can be affected, without altering the strength of the whole.

A usual form of damage is to find that a rib has been broken, although the fabric may not be torn. The best method of repairing this is to remove one panel of fabric (a whole panel replaced is neater than a patch on an existing one) so that the rib is easily reached, cut out the damaged length, and splice in a new piece. The spliced ends should be bound with a strip of fabric soaked in dope, and the fabric panel replaced, doped and varnished.

If, however, the machine is to be used again as soon as possible, the varnish and dope should first be scraped off the fabric along a strip about 2 inch wide, the centre of which is along the damaged rib; and the fabric should then be slit along the whole length of the rib: this should give enough room to work on the break.

A piece of wood similar to the rib strip should be cut, long enough to cover all the damaged part (provided that this is only cracked or split, and is not entirely broken out). This strip should have the ends tapered in thickness only on one side, over a length of at least 2 inches, and it should then be glued on to the inside of the rib with the untapered side in contact with the rib itself. Clamps should be used to hold the joint between protecting strips. When the glue has set and the clamps have been removed, a strip of fabric can be doped over the slit.

The correct way to repair a small hole in plywood is to cut out all the damaged part as a square, circle, or rectangle, and glue stripwood on to the inside of the ply on all sides as a stiffener for the edges. Chamfer the edges down all round on the outer surface for $\frac{1}{2}$-$\frac{?}{}$ inch. Cut a piece of ply of the same thickness as the panel, and of a size to fit over the hole plus its chamfered edges. Chamfer the edges of the patch to match, and glue it into position, using tacking strip to hold it in place. A temporary method of effecting the same repair is to cut out the damaged part so that the edges of the hole do not contain any cracks or splits, and cover with a larger piece of ply whose edges have been chamfered down, this time leaving the chamfering outwards and visible. Glue and hold with tacking

strip until dry. This is an untidy, and very temporary means of repairing ply, and a permanent repair should be effected as soon as possible. If the damaged part is very small, cut out as nearly circular as possible and cover with a patch of doped fabric. This should not be done with holes over 2 inches in diameter, or on the leading edge of the wing.

If damage is caused to the machine when flying, or by a collision while in the trailer, the subsequent inspection cannot be too complete. Any part that is at all suspect should be ruthlessly stripped of its covering and minutely examined. If the initial damage is to the nose and the control installation,

Fig. 80. *Repairs to skid of secondary being made in rural surroundings.*

the cables may have pulled out pulleys near the tail or strained the elevator, or rudder horns, or attachments.

If the machine has made a heavy landing on one wing, the spar or spars in the other wing may even be cracked or the fittings damaged. After any incident, however minor, the whole machine should be looked carefully over for buckling of the ply, or distortion of the fabric. These are good signs of internal damage.

Field repairs (Fig. 80) will be made much easier if adequate tools and materials are carried for this purpose. The most useful being as follows: A spare skid complete with rubber blocks, metal sheaths, bolts, and already varnished; one or two spare

ribs, or assorted rib strip wood; a few ply panels of correct thickness; spare bolts of necessary sizes for all fittings; supply of safety pins, and locking nuts; spare fabric, small tins of glue, dope, and varnish. A small saw and snips for cutting plywood. Brads, small rule, rasp, chisel, sandpaper, and numerous cramps. Normal dismantling tools for sailplane, including tack hammer, drift and pliers, or small adjustable spanner.

These should be enough for ordinary field repairs.

There is only one last thing to say on the matter of repairs, and that is, wherever possible, obtain expert assistance, and if in any doubt as to the extent of the damage or the efficiency of the repair, ground the machine until such times as proper help and facilities are available.

Chapter 12

INSTRUMENTS, RELEASES, TRAILERS AND RETRIEVING CARS

INSTRUMENTS

Essential sailplane instruments are few in number; an adequately equipped panel for general purpose soaring probably containing an airspeed indicator, altimeter, either of the sensitive or non-sensitive type, variometer, turn-and-bank indicator, and small compass (Figs. 81 and 82).

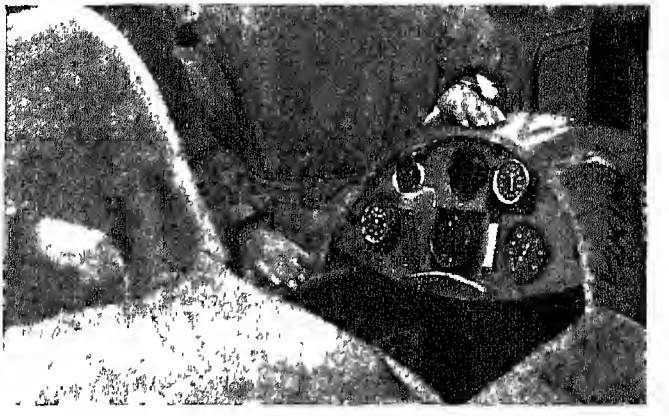


Fig. 81. *Instrument panel of Viking I.*

Variometer

The most important of all is the variometer, which is a very sensitive instrument measuring changes of air pressure. It is required to indicate accurately and rapidly the rate of ascent, or descent, of the machine, and is therefore essential, if available lift and thermal currents are to be used to the best advantage.

The most widely used British type is the Cobb-Slater, which has given outstandingly good results. It consists of two small parallel tubes, tapered from top to bottom, each tube containing a tiny ball: green on the left for indication of upcurrent, and red on the right, for downcurrent. The top of the up tube, and bottom of the down tube, are connected to the outside

air, while the bottom of the up tube, and the top of the down tube, are connected to an insulated air capacity (or two thermos flasks), stored behind the instrument panel.

If the sailplane flies into rising air (or reducing pressure), the relatively higher pressure in the flasks causes the air to flow out from them through the instrument to the atmosphere, and the only way in which it can do this is through the up tube from base to top. In so doing, the flow of air lifts the green

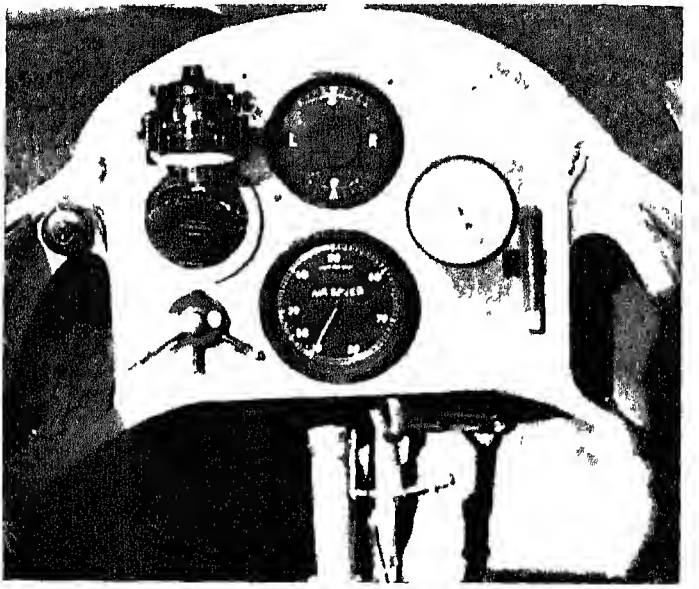


Fig. 82. *Panel of Rhonsperber. Note switch on left for electric-driven turn-and-bank, also roomy pockets on either side.*

ball up out of the base of the tube. The height in the tube to which the green ball is raised indicates the rate of the rising current, and this can be directly read off the printed scale alongside (Diag. 38).

When the sailplane enters a downcurrent, the reverse occurs; the only way the air of rising pressure can flow through the instrument to the bottles (which now contain air of lower pressure) is *via* the tube containing the red ball. The green ball drops back to the tube base and the red ball is lifted.

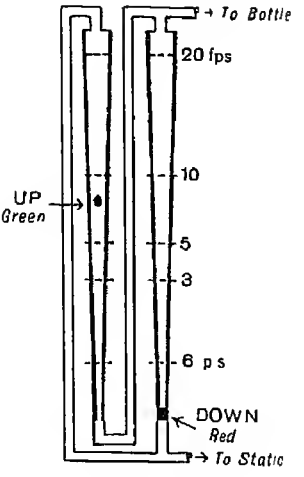


Diagram 38

The American Kollsman and the German Askania variometers are of the capilliary leak type, and consist of a diaphragm (or exhausted capsule) connected by levers to an indicating needle on the dial face. As the varying external air pressure compresses the diaphragm (or allows it to expand) so the needle on the dial face is moved.

Air Speed Indicator

This instrument indicates the speed of the aircraft through the air only, and not the speed over the ground.

Like most flight instruments it relies on air pressure difference for its operation, although in this case the difference created is artificial, and not atmospheric.

The instrument consists of a diaphragm connected by levers to a needle on the dial face. The inside of the diaphragm is also connected to an open-ended tube facing into the airstream where there is no turbulence. The diaphragm container is connected to a static or venturi head located at the same place.

As the air-flow into the open-ended pressure tube increases, so the diaphragm is forced to expand and the needle on the dial indicates an increase in speed, etc.

Altimeter

The altimeter indicates the height of the machine above sea level, or above the height at which it was last reset. It does

not show the height above the country over which the machine subsequently may pass.

The altimeter will only read correctly when the barometric pressure at sea level is 29·92 inches mg. and other conditions, such as temperature, etc., are "standard"

The altimeter can be set according to the conditions of the day, by moving the altimeter barometric scale until it corresponds with the prevailing pressure. It should be remembered that the altimeter will exaggerate your altitude when flying into conditions of lower pressure, and give a falsely low reading when flying into conditions of rising or higher pressure.

The instrument consists of the usual diaphragm connected to the dial face needle, and varying atmospheric pressure on the outside of the diaphragm causes the needle to move.

Turn-and-Bank Indicator

For high-performance soaring a Turn-and-Bank indicator is essential. It has been proved time and again that the human loses all idea of his attitude in space, often after only a few minutes of blind flying in cloud.

The Turn-and-Bank indicator is normally operated by small gyroscopes driven by the airstream *via* a venturi tube. As sailplanes fly at a fairly low airspeed, the venturi has to be very large to be efficient, and for this reason should be retractable when not in use.

A better method of operating the Turn-and-Bank on sailplanes is by a small electric motor driven by a 12-volt dry battery; although this obviously requires regular inspection of the state of the battery if the instrument is not to fail at a most inconvenient time. This method also has the advantage that the venturi tube cannot ice up.

Compass

Ordinary aircraft compasses are usually too big and heavy for sailplane use, and the small direct reading bowl type is more satisfactory, although it cannot be pre-set for any particular course, and is less stable than the standard aircraft type. Sailplane navigation is mostly done by the visual method, by map reading, and it is difficult for the pilot to get enough

practise in this respect if the cross-country flights made are to take every advantage of the available conditions.

The above are the most essential instruments for sailplane use, although many pilots like to add others, sometimes to excess. A few which may be added to some use, and without cluttering up the instrument panel and cockpit are, a hygrometer for measuring the humidity of the air, a sensitive thermometer, an inclinometer, which is quite useful in case of airspeed indicator failure in icing conditions. And lastly, a clock.

Barographs

Any pilot who is seriously considering high-performance work should always carry at least one barograph. It is better, however, to have two: a fairly large one to be stowed in a prepared part of the fuselage and which reads up to 9-10,000 feet, with a drum about a 3-inch diameter revolving approximately once an hour. This will give a very detailed record of ordinary hill-thermal soaring, or cross-country flying. The second barograph can be of the small pocket type, but should read up to 25,000-30,000 feet if possible. It is extremely unlikely that the ordinary pilot will ever reach such heights, but if he ever did, no one would be more fed up with himself if his altitude had exceeded the recording powers of his barograph. The pocket type barograph does not give a satisfactory detailed reading, but a second barograph is valuable in any case if the first one packs up.

A great deal can be learnt from a subsequent study of one's barograph charts when these are checked against the route taken, the time of day, and prevailing weather.

The barograph is also operated by a diaphragm in the same way as the altimeter, but instead of a needle moving on the face of a dial, an inked pen traces the varying altitude on a chart fixed to a revolving drum.

WINCHES

Winches used for the launching of club and private sailplanes have been developed by individuals and small groups to suit their own requirements. There has therefore been no stan-

dardising of winches, or specification drawn up, and consequently no extensive development. The results have been satisfactory as no club can afford to give its members frequently poor or faulty launches.

Winches operated by private groups have shown equally good service, as they have been maintained by enthusiasts who wished to get the maximum from their soaring activities. The total result is, however, that there are many different varieties of winches in general use, each one having its own peculiarities.

An ordinary winch consists of the chassis of a high horsepower car, with a drum mounted either on the transmission shaft aft of the gear box, or on one of the back wheels. The launching cable is wound on to the drum through guides which may take the form of two pairs of rollers at right angles to each other. If the drum is wide, a device for winding on the cable evenly is required. Lastly, an adequate method of severing the cable in case of emergency must be fitted. It is often said that the simpler the mechanical device the better it is: this applies very much to winches, partly as these essential items are apt to take a secondary place to the aircraft in the minds of pilots and club members generally.

It is advisable that the winch should be safely operable by one person, otherwise if occasions arise when there is no assistant available, the driver will be tempted to give launches on his own with possibly dangerous results.

One of the two jobs in which the assistant is mostly needed is that of manually distributing the cable evenly over the drum surface. This can be overcome in two ways, the simpler being to have a very deep narrow drum with wide flanges instead of a wide one, and this will not affect the efficient running of the winch. Secondly; by fitting an automatic distributor; as this requires an additional mechanical device, it is the less satisfactory, although the cable may look very pretty when laid smoothly on the drum.

The assistant's second job is that of severing the winch cable in an emergency. This is usually done by means of cutting the cable with an axe while it crosses a metal plate, or, by hitting a small quillotine with a hammer, or mallet. Neither of these methods are 100 per cent satisfactory, as the time available in which to cut the cable in an emergency is short, and the axe or hammer may have fallen underneath the

winch, due to vibration when launching, or may even have been temporarily borrowed, in spite of the winch driver's vigilance. The actual cutting of the cable is not difficult, as the cable will be moving out only very slowly from the drum at the end of the launch, and will therefore be easy to sever. However, if this operation can be done by the driver without his moving from his seat, so much the better.

The most satisfactory method of cable cutting would seem to be a guillotine in which the blade is held off the cable against a spring that could be released by a finger-light trigger or bowden cable control. The release control should be fitted to obstruct some previously necessary control such as the ignition switch, in order that the pre-setting of the cutter would be ensured.

Some winches are operated with the driver facing, and others with the driver sideways on, to the launch. There is no actual advantage in either method, except for personal preference and habit. With the back wheel drive winch the driver faces the launch, and with the normal shaft drive winch the driver is sideways on, with the cable coming straight off the drum through rollers mounted above the running board.

The Hatcher winch, which is of the shaft drive type, possesses the advantages of both the above types. It is fitted with a welded angle iron pylon above the drum topped by a universally mounted pulley through which the cable runs. The machines can therefore be launched in any direction from the winch without altering the latter's position—an asset on days of variable winds. Also, the driver can sit facing the way he prefers. The pylon has another advantage in that as the load is taken up at the commencement of a launch, the cable running from the pylon top causes the frame and chassis to heel slightly from the springs and this lessens the chances of snatch or stalling the engine (Diag. 39).

The best types of chassis to choose for conversion into winches for club operation are those with high-powered large-bore slow-speed engines of about 40 h.p. The small-bore high-speed engine is apt to have its power affected by varying loads on the launch, such as gusts, bucking of the machine, etc., and consequently will not give such a smooth steady pull.

Lower horse-power winches can be used on clubs, but about 40 h.p. is really required for all-round work where two-seaters are used, and where the winch is working constantly.

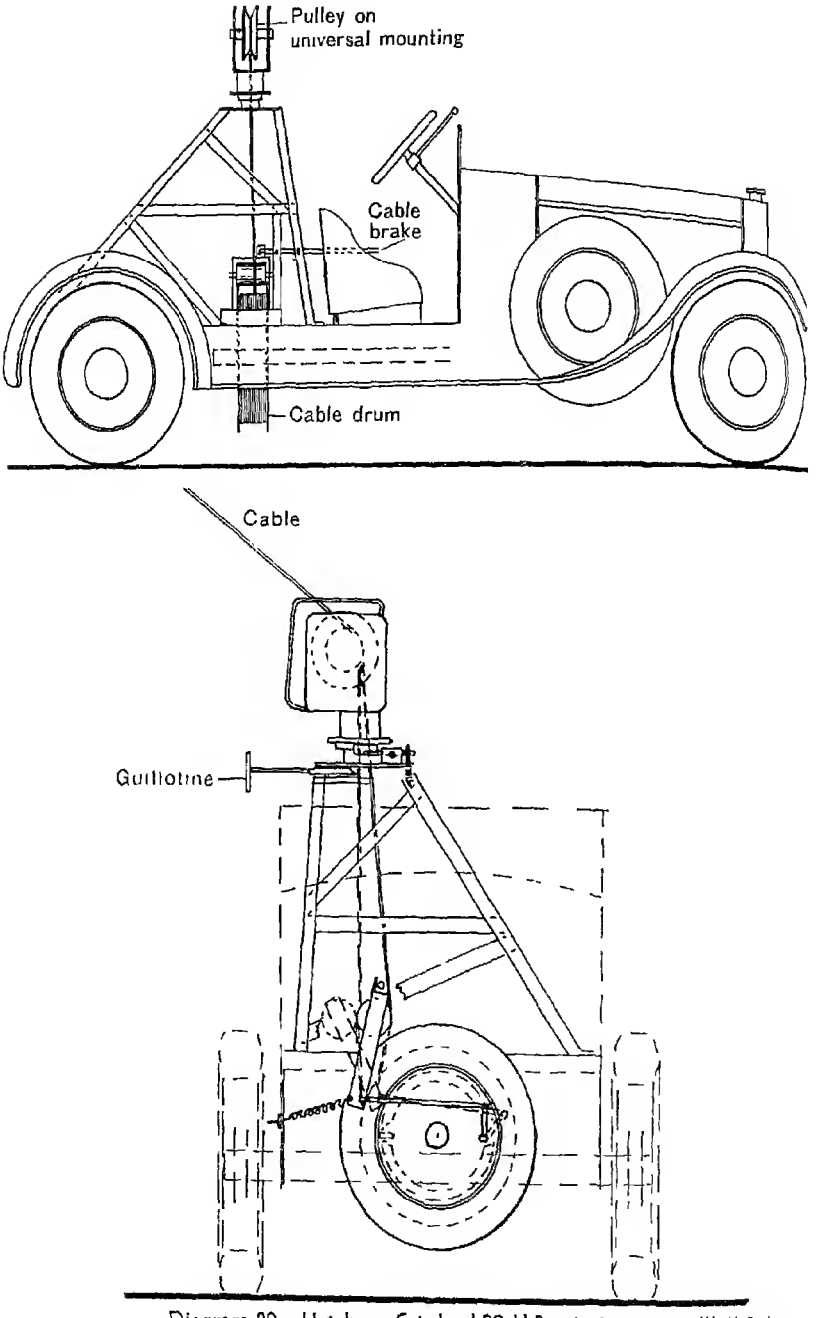


Diagram 39. *Hatcher - Copeland 39-H.P. winch.* F. W. M. Ruck

As one tendency in sailplane design seems to be in the direction of increased weight, this should be reckoned for when obtaining club winches. If the power available is more than required, it need not all be used, but too little power can be a strain on the winch engine, and a source of annoyance to the pilot who feels he has been cheated out of a few hundred feet.

Club winches should, if possible, have a self-starter which works, although, of course, this need not be continually used; otherwise, to save getting out and cranking, the driver may be inclined to leave the engine running for considerable periods with resultant overheating, and heavy petrol consumption. A spare battery should be kept, and the battery in use re-charged before it is flat.

Winches used by groups, or those which are only giving infrequent launches, need not be fitted with a self-starter, provided that cranking is not too tiresome a procedure.

With regard to winch controls; the clutch can be satisfactorily operated by the foot, although an exceedingly long clutch travel should be avoided. The throttle, however, is better operated by hand, on a fairly sensitive lever; this can be easily arranged for, whereas conversion of the clutch from foot to hand operation is much more complicated.

A drum brake is a useful addition, and is very easily fitted on shaft drive winches by fitting a long lever arm, tipped with a wooden shoe and pivoting near the shoe, with the handle end alongside the left of the driver's seat and the shoe on the face of the drum. The shoe is held downwards off the drum by a light spring. To apply the brake, the driver presses the lever arm down, against the spring.

During thundery weather winches should be earthed, and the earth wire and stake should be permanently attached to the winch so that this is not left behind when the winch is moved.

Some people prefer a speed indicator of some kind for a guide when winch-driving. Such an instrument is not only unnecessary but is even a disadvantage and maybe a danger when launching trainees. The driver should keep his eyes on the machine he is launching the whole time it is on the cable, and he should be capable of judging the correct speed of each launch by the appearance and behaviour of the sailplane, and not by either a mechanical speed indicator, which makes no

allowance for wind speed and machine attitude, or by the sound of the winch engine. If the winch driver is not capable of this, he should not be launching any type of machine, or pilot, except under supervision.

Experiments are now in progress with a cable tension control. This should be of real assistance to the winch driver.

Winch Cables and Ropes

Cable used for launching is of the flexible multi-stranded type, usually galvanised, although the author prefers extra flexible stainless steel cable, which costs more, but has a longer life and, due to its flexibility and good wearing qualities, can be used in a lighter weight than would be otherwise practicable. A 10-cwt. cable of the above type being suitable for all club work.

Some cables are cored with fibre. This is a mixed blessing as although it reduces wear due to kinking and bruising, the core is liable to rot if continually in contact with wet ground and changes of temperature and humidity.

An alternative to steel cable for launching is manila rope, of $\frac{3}{8}$" - $\frac{5}{8}$" diameter for training and $\frac{3}{8}$" - $\frac{1}{4}$" diameter for high launches. Rope gives a softer and smoother launch than does wire cable, but has a shorter life, and breaks cannot be safely tied like cable, and have to be spliced each time.

RELEASES

Quick releases are used for two essential purposes. Firstly, the sailplane is equipped with a quick release for getting rid of the cable at the end of a launch. Secondly, any aeroplane, or car, used for towing must also have a quick release at its end of the towline. This is necessary for the safe operation of gliders, and such releases must be carefully designed and properly maintained.

The Otfur glider release has a device whereby the jaws are automatically opened, if there is a backward or sideways pull on the cable.

Fig. 83 shows a typical aeroplane quick release and (Diag. 40) a weak link.

Release rings should be securely spliced to the cable *via* a thimble, and rings should be made from mild or high-tensile steel, and never from malleable or cast steel.

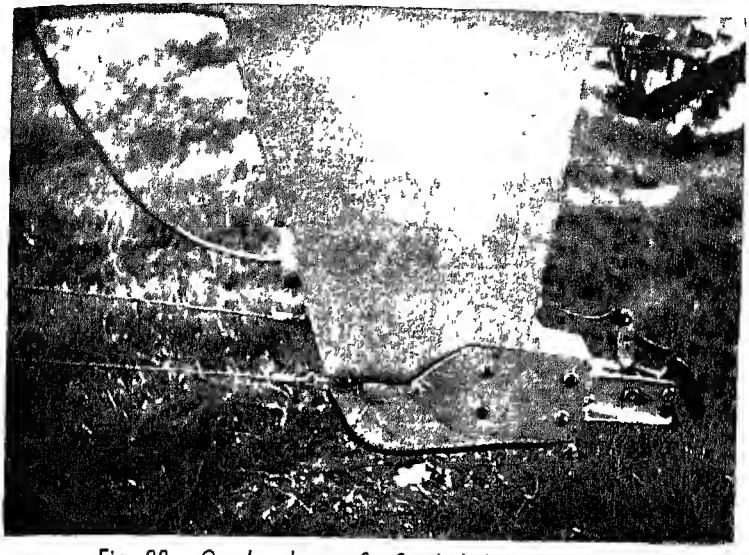


Fig. 83. *Quick release aft of tail skid on Avro 504n.*

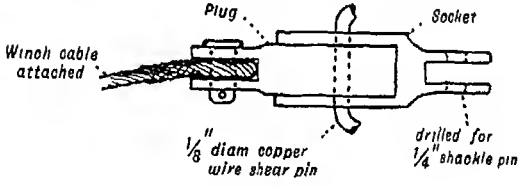


Diagram 40

TRAILERS

To any pilot who is considering cross-country flying, a properly equipped trailer is essential.

Trailers consist of a carrier for the complete machine when dismantled, on a centrally mounted pair of wheels, and with an adequate draw bar. Trailers should be carefully designed with regard to disposal of load, and height of draw bar in relation to towing cars attachment, etc. A good trailer which runs true behind the car can be no trouble at all, but one in which the draw bar fits badly, or in which the weight is too far aft, or which trails tail down, can be a tiring and annoying appendage, and may even take over control of the car if the driver is careless.

Trailers must by law be fitted with automatic brakes which come into play whenever the trailer tends to overrun the car; diagram 41 shows the normal simple method of doing this. With a light car and a heavy trailer, however, the brakes can sometimes be a nuisance as they jerk the car whenever they come into use.

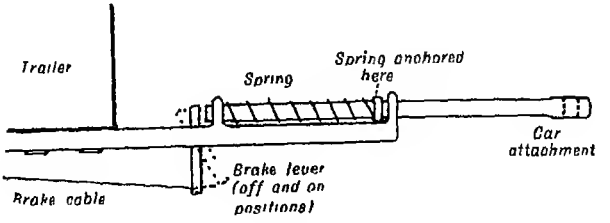


Diagram 41

As regards the design of the body of the trailer, there are two varieties in common use, the open type, and the closed type.

The open type consists of a braced or cantilever platform, on to which are mounted simple supports for wings, fuselage, and tailplane (Figs. 84 and 85). The open type trailer is usually constructed so that it will take almost any kind of orthodox glider or sailplane without alteration to the trailer. Attachment of the components to the supports being by straps or tapes. This type of trailer is the better for club use, where varying types of machines are used which may have to be fetched back from deliberate, or inadvertent, cross-country flights, or where damaged parts are to be taken away for repair. Its disadvantage is that it is neither water nor weatherproof.

Fig. 84. *Loading the white Wren on to open-type trailer.*

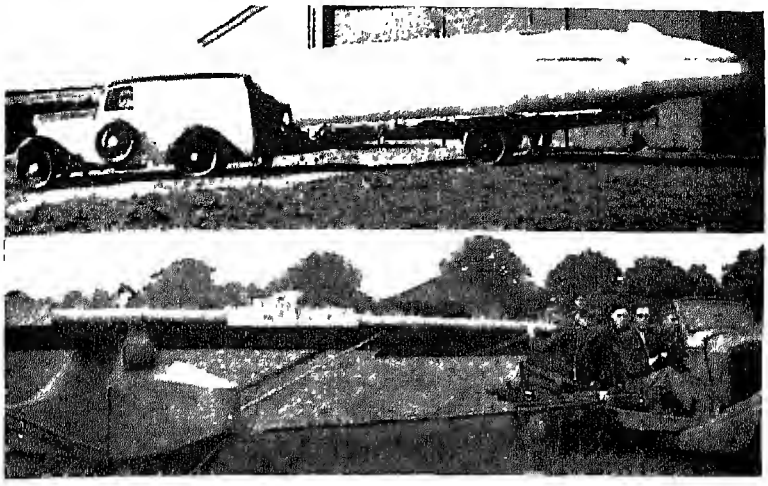


Fig. 85. (*Top*) *Cambridge II on open-type trailer, rudder can just be seen above aileron.* (*Bottom*) *retrieving Cadet trainer by boom method described on page 299. Note "spoilers" to prevent machine becoming easily airborne, as in diagram 36a.*

The enclosed type of trailer is really necessary for the private owner, whose machine frequently lives in its trailer when it is not being actually flown. The most satisfactory form of construction for this type of trailer is where a stressed ply wood skin is cold glued on to a light wood frame. The floor or platform is made from three or four 2 inch by 4 inch planks lying on edge lengthwise, and covered by $\frac{1}{2}$ inch planking athwartships. The formers for the sides and walls are then screwed and glued to the floor and the whole is covered with $\frac{1}{8}$ inch ply wood sheet, which is glued to the floor and formers, the whole making a rigid box. Ply ends and light doors are then attached, and the whole is covered with fabric and protected by several coats of paint.

The internal fittings are made to fit one type of machine only, so that it may be quickly and securely stowed in the confined space with little effort.

The enclosed trailer also provides a good shelter from the weather for the crew when the machine is being flown from unequipped sites, and the interior can be easily fitted up with electric light, small tool racks and convenient stowage of spares, or even with the wherewithal for light refreshment.

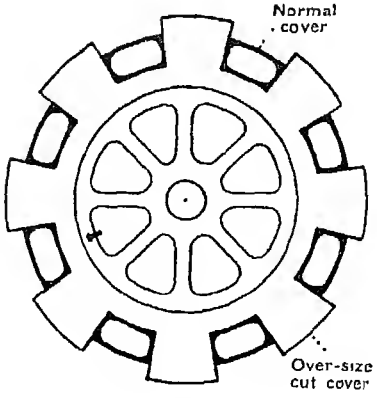


Diagram 42

Retrieving Cars

Properly equipped retrieving cars will cut down delays in club flying very considerably, although it is often supposed that anything that will move under its own power is good enough. The car should run reliably and in winter be equipped with special wheel grips to overcome the mud and soft ground of the landing field. A satisfactory method of doing this is to fit oversize tyre covers to the rear wheels which have been cut as shown, on top of the normal covers (Diag. 42).

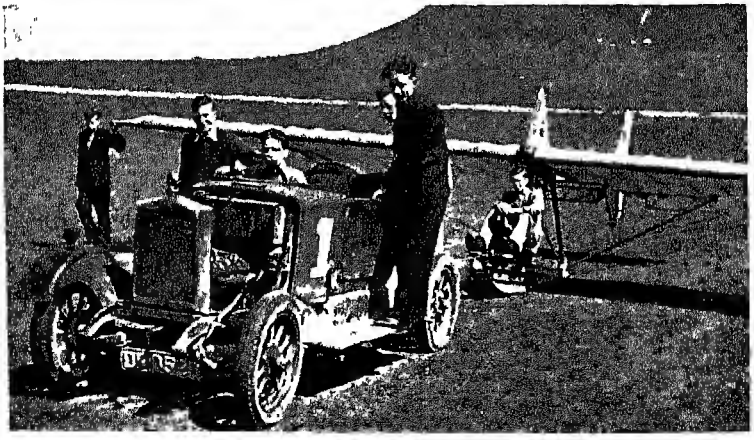


Fig. 86. *Retrieving by a slow method.*

These oversize covers can be obtained quite cheaply as it does not matter if the walls are damaged.

The most usual method of retrieving is to simply connect the rear of the car to the nose release of the glider with a 6-10 ft. rope or cable, with the pilot running, or walking, at the wing tip (Fig. 86). This is a slow method as the wing-tip man cannot move very fast, and there is also the danger of the machine trying to take off, or even blowing over backwards, if the weather is very gusty.

A method which overcomes both these faults is to fit the retrieving car with a wire-braced metal boom at right angles to and below the driver's seat, about 15 ft. long, the end of which is approximately the height of the glider nose release, to which it is attached by 8 inches of wire cable. This will not allow the nose to be lifted by gusts more than a few inches off the ground. The wing of the glider passes over the rear of the retrieving car and is held by a man seated behind the driver (Fig. 85). By this means the time taken to retrieve each glider is reduced, as the car can be driven at a considerably higher speed.

Chapter 13

SOME WELL-KNOWN HILL SITES

The Derbyshire and Lancashire Site in the Peak District

The Derbyshire and Lancashire site lies in the midst of the backbone of high ground which runs down the centre of England, and is three miles from Tideswell Village and twelve miles to the south-west of Sheffield. On the map it appears insignificant as it is surrounded by other hills as high or higher than itself. It is, however, a most effective hill-soaring site; its only disadvantage being that the height above sea level of the immediate countryside, some of it rising to over 2000 feet, means that it is sometimes enveloped in cloud when the weather on the plain is good for flying.

The buildings, and extensive landing ground, are on the flat hill top, and the club buildings usefully sheltered in a little hollow. Two slopes are used. The west slope, called Bradwell Edge (Fig. 87), and the south slope of Eyam Edge. Both have

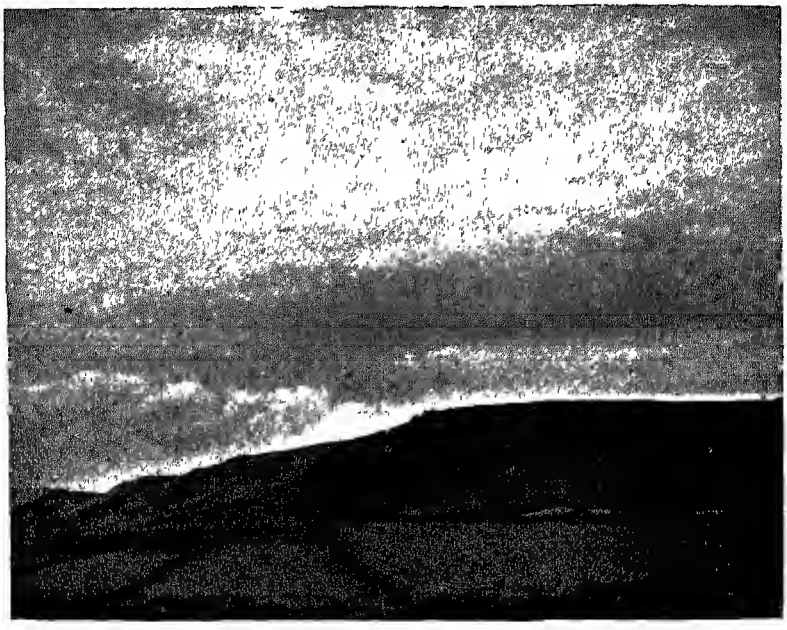


Fig. 87. *Bradwell Edge: the west slope of the Derby and Lancs. club.*

beats of about two miles and provide good and fairly smooth lift, although the hillside is somewhat dotted with small trees. The height above the valley is in each case about 4-500 feet. The ground is mainly carboniferous, being coal and culm measures, and millstone grit, while away downwind several different and narrow strata lie across the track of the more usual cross-country flights. The thermals are frequently excellent over much of the early part of this plain, and this may be explained by the contrast caused by these layers. Thermal lift around the site is quite good, but often broken, due no doubt to the nature of the surrounding country.

This site has, however, proved itself an excellent competition site, being the start of many first-rate cross-country flights.

DUNSTABLE

This is perhaps the best known site in the country, and although by no means perfect, has been so much explored, that most of its faults are naturally and easily avoided. It is also one of the lowest sites in the country, the effective height of the hill being little more than 200 feet and of fairly shallow average slope. It produces, however, very adequate lift and numerous thermals.

The main slope of two miles faces slightly north of west (Fig. 88) and is topped by a south-west facing bowl, which although of extremely limited beat adds considerably to the all-round usefulness of the site. Three miles south of the main ridge, and beyond Whipsnade Zoo, is, however, a further slope which can be used in south-west winds, and this helps to relieve congestion in the bowl.

The landing ground, which is of considerable size, although by no means flat, is at the foot of the hill, and the whole region lies on the chalk, of which the hill surface is also composed.

The buildings are the most up-to-date of any in the Country and comprise club house, hangar, workshops, offices and sleeping accommodation.

The site lies two miles to the south-west of Dunstable town on Watling Street, and eight miles to the west-south-west of Luton.

Hill soaring is also possible in south-westerly winds on Ivinghoe Beacon five miles to the south-west of the site, and

Fig. 88. *The westerly face of the Dunstable Downs.*

this provides an interesting excursion to vary with flights along the home slope.

The Furness Club

The Furness club, which owes much of its rapid progression to the energies of the late Frank Charles, has it headquarters near Ireleth, above Askam-in-Furness, and uses the west-north-west slope immediately to the north as its main soaring ridge, which is about 600 feet above sea level. Other sites used include

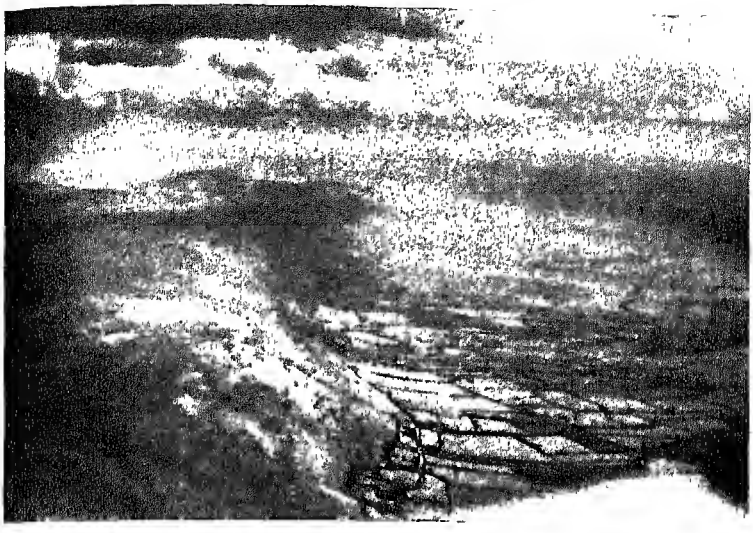


Fig. 89. *The west slope of the Long Mynd: the hangar can just be seen as a white patch on the hilltop on the left.*

an east slope at Lindale-in-Cartmel, fourteen miles to the east near Grange, and Black Comb mountain on the far side of the Duddon Estuary above Millom.

There is a large hangar on the hilltop of the home site, where training is carried on.

The Midland Gliding Club on the Long Mynd

The site of the Midland club is one of the best one-direction hill-soaring sites in the Country, being excellent for most variations of the west wind (Fig. 89).

The Long Mynd is about fifteen miles south-south-west of Shrewsbury and the hill crest is about 1600 feet above sea level and nearly 1000 feet above the valley. The contour is good and the hill surface unobstructed, lift being strong and smooth, and ideal for early soaring, or for that matter, anyone who wants a most pleasant and peaceful afternoon in the air.

Lift of a standing wave variety has been found above the Mynd, which has provided lift to 7000 feet under certain conditions.

The club buildings, and all launching and landings except emergency landings are done on the hilltop, the hangar having been built to resist gales up to 130 m.p.h.; necessary in so

exposed a spot. Much of the hill top surrounding the actual landing area is heather covered, and the gentle descent to the rear of the hill face does not cause much of a down-draught, which might otherwise make approaches difficult. The hill is composed of pre-cambrian stone and the site itself produces quite good thermals.

The Newcastle Club

The Newcastle club has its headquarters and training ground at Cramlington, eight miles north of Newcastle-upon-Tyne, and uses various hill sites at such places as Chillingham, Weetslade Moor, Green Hill, and Great Tosson, some 18-30 miles to the north-west where soaring is possible in winds varying from south-west to north-east.

A further site, which has been extensively explored by the Newcastle club, is Cross Fell on Hartside. This is on the long south-west face of the Pennines, forty miles from Newcastle, overlooking the Eden Valley, and stands nearly 3000 feet above sea level and about 2400 feet above the valley floor. This site has extremely interesting characteristics and possibilities; the hill itself is so high that the normal hill lift does not occur over and ahead of the hill crest, but starts some distance out from the hill at about half the hill height.

In some conditions of easterly wind, however, a standing wave occurs, with the wind rushing down the hill face in a torrent and the air then rising above the valley to a height of many thousand feet. N. MacClean, a pilot of the club, reached nearly 11,000 feet in a G.B.II medium-performance sailplane after being winched into the estimated position of the updraught. The war unfortunately put a temporary end to further experiments.

The North Downs Range

The Surrey Gliding club operated along the part of this range between Reigate and Dorking before the war, using a 55-acre field at the foot of the hill near Buckland. Use was made of the sheltered nature of this field which allowed all launches to be made parallel to the hill, with the consequent simple connection with hill lift, and the infrequent movement of winch and launching directions.

Fig. 90. *The North Downs looking west towards Box Hill.*

The soarable beat in south and south-west winds is three miles in light winds, and six miles if the wind increased or thermals could be used to bridge the small Pebblecomb break; this length of beat prevented congestion around the training area. The lift produced by the hill, which was extensively covered by trees, was higher than average, although the air was frequently rough.

The North Downs range, with three further hill soaring areas, extends from the Medway in the east to Guildford in the west, where it peters out. A further south-west ridge runs from the far side of the Medway Valley down to Ashford in Kent, and although little of this is actually soarable, it is excellent for the production of thermals. The valley at the foot of the whole North Downs range is surprisingly good in this respect, being on sand below the chalk uplands. The hill soaring parts of the range vary between 250 and 400 feet above the valley and average between 750 and 800 feet above sea level (Fig. 90).

The Portsmouth Club

This club has been revived since the end of the War, and uses the south-facing Portsdown Hill, which reaches 409 feet above sea level. In north winds the site at Kithurst hill provides good lift.

Old Winchester hill provides slopes facing E. and S.W.-N.W., having, in addition, an auto-towing run of nearly a mile, from which all its slopes can be reached.

The South Downs Club

The South Downs sites have quite a historical interest as it was on these north facing chalk slopes that the first British open gliding contest took place in 1922.

The downs which are steep and mostly bare run roughly parallel to the south coast several miles inland and extend for over forty miles, although only short stretches are soarable. The range has a slightly north-east set, and the general attitude is not conducive to thermals, nor is the proximity to the coast favourable for cross-country flying, unless the channel is to be crossed as a matter of course.

There are three sites, all within ten miles of Brighton, which are useful for hill soaring. The Devil's Dyke, which is a north-west facing bowl only has a limited beat, but is suitable for bungey launches from the top, and has quite good landing space at the bottom. The most easterly site, Firle Beacon, also has a short beat, and is suitable for north-east winds. At Ditchling Beacon, there is a good beat of about five miles facing slightly east of north. Launching and landing are possible at both bottom and top of the hill.

Oxford University and City Club

This site lies at the foot of the Chiltern Hills at Aston Rowant, on the main road from Oxford to London. The landing field is large enough for winching purposes, although slightly on the short side at right angles to the hill (Fig. 91).

Although not ideal as an early hill-soaring site, due to the nearest beat being a spur without much length, which is also on the far side of a railway cutting, it is extremely good as a starting place for cross-country flights by advanced pilots. This is because there is a soarable beat in north-west winds of over three miles which can be reached by medium- and high-performance sailplanes. Such a length away from the actual landing field reduces congestion, especially in the training area, while pilots are searching around for lift prior to going away. This beat of three miles can also be extended with the assistance of thermals over much of the length of the Chilterns which provide entertaining and instructive flying.

The hills are chalk and partly wooded, while the land along the foot of the range is mostly arable, with small villages.

The Wiltshire Group

On and around Salisbury Plain there are a group of gliding and soaring sites which have been explored widely in the past

Fig. 91. *The Home slope and landing field of the Oxford Club.*

by nomad parties and clubs, especially the Cambridge University club, who used it for training and advanced soaring camps.

The base from which the majority of the expeditions operated was at Huish, near Pewsey, about five miles to the south of Marlborough on the Bath Road, and there are four widely used sites.

At Huish itself there is a southerly ridge, which can also be used in south-west winds. This gives hill soaring on beats of half a mile to 5-6 miles, depending on wind strength and direction. The site produces very easy soaring conditions as the downs are smooth contoured and bare, and landings are quite simple in any of the many big fields lying along both the bottom and top of the hill (Fig. 92).

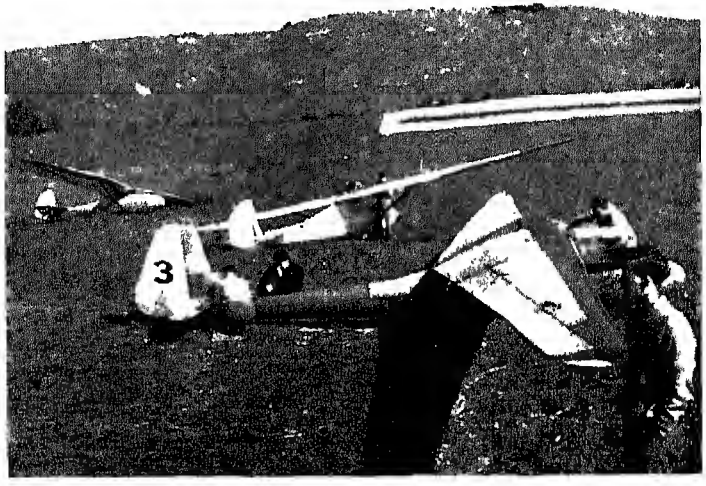


Fig. 92. *Rigging sailplanes in the landing field at Huish (foreground Rhonadler).*

Nine miles to the west of Huish, is Roundway Down, just to the north of Devizes. This is a west wind hill site of limited beat, in which all launches and landings are made from the rolling expanse of downland on the hill top. Landing is possible, but not extremely easy, in the fields at the bottom.

The one-mile beat is divided into two parts. The more northerly is bare and smooth contoured and is sometimes used

for launching by bungey, but does not provide such good lift as the more southerly half which is steeper and entirely covered with trees. The flight from Roundway back to the base at Huish has been frequently made by pilots who have preferred to fly home rather than land and trail back by road.

The northerly facing ridge at Inkpen, twelve miles to the east of Huish, provides good soaring on a 3-4 mile beat in fresh north winds and a short beat of a bare mile in north-east winds. As this is, however, one of the very few north-east sites in the country, it has been gratefully used.

Launches and landings are made from a concave field at the foot of the hill midway along the ridge and emergency landings are possible on top. The hill possesses good shape and is not very turbulent although studded with trees, bushes, telegraph wires, aerials, and a gibbet! (Fig. 93)

Perhaps the best site of the four is the north-west wind site on Whitesheet Hill between Salisbury and Shaftesbury, although it is perhaps the least used, due to the distance from Huish, of about thirty-eight miles.

It has a beat of 5-8 miles, depending on conditions, and provides smooth slope lift over land excellent for the production of thermals. Landing is possible almost anywhere on the open downs, or the large fields at the foot.

The hilltops on all four sites are between 200 and 300 feet above the valley, the crests varying between 700-975 feet above

Fig. 93. *The northerly hill-face at Inkpen Beacon.*

sea level. These sites form a most useful group, as hill soaring is possible in all winds except east and south-east, which are not frequent, and are often stable.

The surrounding countryside is excellent for thermals, and provides numerous easy landing fields, ideal from the advanced training point of view.

The whole area is chalk downland except the east-west valley between Pewsey and Devizes, which is sandy. There is also a similar strip at the foot of Whitesheet hill.

The Yorkshire Club Site at Sutton Bank

This hill site is situated at the south-west end of the Hambleton Hills, seven miles from Thirsk (Fig. 94).

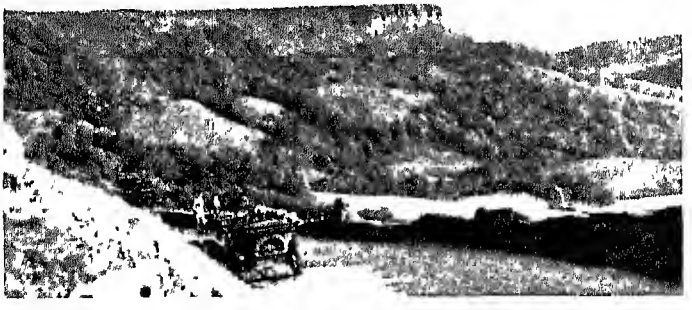


Fig. 94. *The west face at Sutton Bank.*

The landing area and buildings are on the heather-covered hilltop, although there is sufficient space for emergency landings in the valley. Two directions are available, the west-facing slope giving the better lift on a beat of about three miles. The south slope has a shorter beat and the lift there, although adequate, is not quite so good. The hill crest is 800 feet above sea level and 400 feet above the valley, which is wide and unobstructed.

The site and the hilly ground to the north-east is composed of oolitic limestone with boulder clay deposits and it is noticeable that practically no cross-country flights have been made

above this area, all going either to the north, or mostly to the south of it, over the alluvial deposits and chalk area to the south-east. This, of course, will have been assisted in addition by the more unstable north-west winds. Immediately upwind of the west slope of the site, the soil is sandstone, quite a good thermal producer.

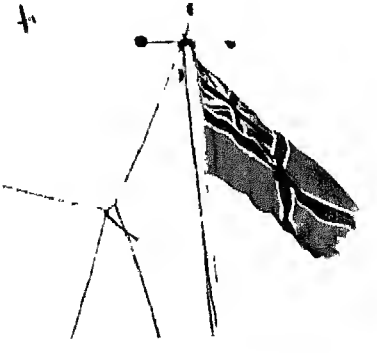
One disadvantage of this otherwise excellent hill site is its proximity to the sea, necessitating considerable cross wind flying to travel any distance.

The Ulster Club

The Ulster club uses as its main site Magilligan Strand, on the eastern edge of Lough Foyle, obtaining lift in a west-north-westerly wind from the cliffs and Binevenagh mountain. All landings and launches are made on the long stretch of hard smooth sand.

Launches are made by auto-tow, using 1000 feet cable, and although 600-700 feet can easily be reached, 200 feet is usually enough to contact the broad belt of hill lift. This lift is very smooth, although without frequent thermals, and gives plenty of space for general flying to a height of about 2500 feet. Near the cliff face, however, are some turbulent patches, due to the abrupt shape of the cliff, but as lift is plentiful there is no need for hill scraping.

Training is carried out dual on a Falcon III two-seater, which is followed by solo flying in Cadet and G.B., etc.



APPENDIX I

GLIDERS AND SAILPLANES OF BRITISH DESIGN

	Purpose and Performance	Span	Length	Wing area (□′)	Aspect ratio	Wing loading	Section	Weight empty	Weight loaded	Gliding angle	Sinking speed	Stalling speed
Slingsby Primary ..	Trainer	33	17.10	163	6.6	2.3	Göt 326	180	380	1 in 10	4½	25
„ Cadet ..	„	39	21	170	8.6	2.6	Got 426	260	440	1 in 15	3¼	28
„ Tutor ..	„	43.4	21	158	11.9	3	Got 426	—	—	1 in 18	3.75	28
„ Falcon I ..	„	42	17.4	195	9.1	2.8	Got 535 (mod.)	386	530	1 in 18	3	28
„ Falcon III ..	Open two-seater light wind sailplane ..	58	22.5	285	11.8	2.8	Got 585*	500	830	1 in 20	3.1	28
„ Kite I ..	Medium performance	47	19.5	156	13.4	2.9	Got 535	270	460	1 in 20	2.5	29
„ Gull I ..	Medium—advanced	50	22	160	15.8	3.13	NACA 4416 RAF 34 tip.	318	510	1 in 23	2.31	27.5
„ Gull II ..	h.p. two-seater ..	60	25.2	212	20.1	3.65	4418-RAF 34	530	920	1 in 29.5	2.25	35
„ Gull III ..	Cantilever medium advanced	50	22	160	15.8	3.48	NACA 4416 RAF 34	376	700	1 in 25	2.2	29.2
„ Petrel I ..	h.p. sailplane ..	57	23.10	—	—	—	—	—	—	—	—	—
„ Petrel II ..	h.p. sailplane, new model	57	23.10	—	—	—	—	—	—	—	—	—
„ 20 Elementary	Two-seater trainer ..	54.6	24.3	290	10	2.9	NACA 4412	507	850	1 in 18	2.9	29
Baynes Scud III ..	Medium performance	45.6	22.5	120	16	3.75	—	—	450	1 in 24	2.2	—
Scott Viking I ..	Medium—advanced	51	—	171	15.4	—	—	370	540	1 in 23	2.5	—
„ Viking II ..	h.p. two-seater ..	61	22.1	235	16.3	3.8	—	510	910	1 in 24	2.4	37
Z and W Cambridge II	Medium performance	46	21.4	160	13.24	2.8	Got 535	245	450	1 in 19	3	26
Dunstable Kestrel ..	„ „	40	20	150	11	2.77	—	245	415	1 in 18	2.9	28
Baynes Scud II ..	„ „	40	17	100	16	3.5	Got 652	119	320	1 in 22	2.2	26
Camel	„ „	37.4	17.2	110	12.7	—	Got 535-M6	—	—	—	3	32
Hjordis	High performance ..	51	21.6	124	21	3.88	Göt 652	310	480	1 in 24	2	35

* Modified, with symmetrical tip

APPENDIX II

BRITISH HOLDERS OF INTERNATIONAL SILVER AND GOLD "C.'s"

Silver "C." Tests.—Climb of 1000 metres, distance of 50 kms, and duration of 5 hours.

Gold "C." Tests.—Climb of 3000 metres, distance of 300 kms.

Silver "C.'s"

	British No.		*International No.*
1934	1	G. E. Collins	26
	2	P. A. Wills	45
1935	3	R. G. Robertson	75
	4	S. Humphries	85
	5	J. C. Neilan	174
	6	C. Nicholson..	177
	7	Naomi Heron-Maxwell ..	208
1936	8	P. M. Watt	241
	9	H. C. Bergel..	244
	10	A. L. Slater	291
	11	G. O. Smith	298
1937	12	J. S. Fox	338
	13	R. S. Rattray	542
	14	P. B. N. Davis	543
	15	G. H. Stephenson	545
	16	D. G. O. Hiscox	560
	17	K. G. Wilkinson	561
	18	J. E. Simpson	562
	19	J. V. Rushton	563
	20	G. A. Little	564
	21	K. Lingford	565
	22	J. S. Sproule..	566
	23	K. W. Turner	567
	24	E. J. Furlong	568
	25	S. C. O'Grady	585
	26	E. E. H. Collins	594
	27	J. L. Wordsworth	595
	28	Joan Price	621
	29	G. M. Thompson	622
	30	L. R. Robertson	625
1938	31	E. Thomas	856
	32	I. Pasold	857
	33	H. Tudor Edmunds.. ..	858
	34	J. C. Dent	859
	35	L. H. Barker	860
	36	D. F. Greig	861
	37	A. J. Deane-Drummond ..	1004
	38	A. Ivanoff	1005
	39	A. W. Lacey	1006
	40	M. H. Maufe	1007

BRITISH HOLDERS OF INTERNATIONAL SILVER AND GOLD "C.'s"

	Silver "C.'s" *British No.*		*International No.*	
	41	J. Parker	1008	
	42	E. H. Taylor..	1009	
	43	K. M. Chirgwin	1061	
	44	R. Pasold	1062	
	45	J. W. S. Pringle	1063	
	46	J. A. Rooper	1064	
	47	J. H. Saffery	1093	
	48	P. M. Thomas	1094	
	49	G. L. Raphael	1095	
	50	A. Davies	1096	
	51	L. C. Withall	1278	
	52	F. Charles	1279	
	53	C. J. Wingfield	-	International numbers discontinued September 1939. All gliding ceased in the U.K. during the war years.
1939	54	F. T. Gardiner	—	
	55	A. P. Pringle .. .	—	
	56	G. H. Briggs	—	
	57	D. R. C. B. de Sarigney ..	—	
	58	R. C. Pick	—	
	59	A. A. J. Sanders	—	
	60	P. Brown	—	
1946	61	C. Ramsay	—	
	62	Ann C. Douglas	—	
	63	J. S. Armstrong	—	
	64	J. A. Pressland	—	
	65	O. P. Wingfield	—	
	66	S. G. Stevens..	—	
	67	T. S. Haynes	—	
	68	Prince Birabongse	—	
	69	H. Neubroch..	—	
	70	R. C. G. Slazanger	—	
	71	W. Tuck	—	
	72	R. C. Forbes	—	
	73	M. Twomey	—	
	74	H. Trybulec	—	
	75	L. Welch	—	
	76	F. M. Reade	—	
	77	R. C. Reid	—	
	78	D. L. Hughes	—	
	79	R. H. Hamlin	—	
	Gold "C."			
1938	1	P. A. Wills .. .	3	

APPENDIX III

INTERNATIONAL RECORDS (1.10.46)

Single-Seaters				
Distance U.S.S.R.	Klepikova (Miss)	in Rotfront 7	6 7.39	466 miles
Out & Return „	Kimelman	„	23.7.39	212 „
Goal Flight „	Satzov	„	31.7.39	374 „
Altitude Germany	Ziller	Kranich ..	11.11.38	22,434 feet
Duration „	Schmidt	G.B.II ..	3-4.8.33	36h. 35m.
Multi-Seater				
Distance	Kartachev-Satzov	—	17.7.38	385 miles
Out and Return, U.S.S.R.	Kartachev-Chechoulkine	Stakhan ovetz	23.7.39	212 „
Goal Flight „	Kartachev-Gorokhova	do.	1.7.39	246 „
Altitude Spain ..	Gomez-Jose ..	Kranich ..	18.9.37	18,776 feet
Duration „	Bodecker-Zander ..	do. ..	9-11.12.38	50hrs. 25m.

BRITISH RECORDS

Single-Seater				
Distance	Wills	Minimoa ..	30.4.38	209 miles
Out and Return ..	Murray	Rhönbussard	7.4.39	68 „
Goal Flight ..	Wills	Weihe ..	27.7.46	113 „
Altitude	Wills	Weihe ..	1.7.39	15,247 feet
Duration	Young	Falcon II ..	18.8.38	15h. 47m.
Multi-Seaters				
Distance	Sproule-Suthers ..	Kranich ..	6.7.46	103
Out and Return ..	——	—	—	—
Goal Flight ..	——	—	—	—
Altitude	Furlong-Johnson ..	Kranich ..	4.7.56	3,601 feet
Duration	Murray-Sproule ..	do. ..	9-10.7.38	22h. 13m.

INDEX

Abrial, 27
Adiabatic, 121, 124, 131, 158, 161
Aero-towing, 45, 73
Ailerons, 59
Altimeter, 287
Altitude flying, 192
Alto-cumulus, 153
Alto-cumulus-castellatus, 154, 163
Alto-stratus, 154
Aluminium, 271
Anabatic wind, 126
Anticyclone, 158
Ash, 270
Aspect ratio, 248
A.S.I., 287
Atalanta, 220
A.T.C., 60, 93
Auger, 27
Austria, 220
Auto-towing, 37

Balsa, 270
Barringer, L., 239
Baragraph, 289
Bezmiechova, 27, 29
Blackmore Vale, 216
Blaue Maus, 219
Blind flying, 202
Borelli, G., 11
Botsch, A., 20
Bowlus, W. Hawley, 28
Bradwell, Edge, 203
Briegleb, 228
Brunt, Prof. D., 144
Bungey launch, 33
Buxton, G. M., 203

C. of A., 106
Cable (launching), 44, 272, 294
Cadet, 94, 108, 222, 225
Cape Cod, 28
Camel, 244
Chanute, Octave, 14
C. G. Hook, 44
Circuits, 67
Cirrus clouds, 157
Cloud streets, 144
Clothes, 176
Cockpit, 265
Cold front, 167
Collins, G. E., 218
Committees, 103
Compass, 288
Condensation, 131, 133
Controls, 55
Convection, 120
Cross Fell, 201
Cumulo-nimbus, 149, 162, 192, 194
Cumulus, 133, 135, 141

Dagling, 222
Depression, 163, 165
Derby and Lancs. Club, 300
Deutchmann, H., 29
Dihedral, 250
Dines, 113
Dive Brakes (air), 193, 242, 263
Dope, 271
Douglas, Ann, 144
Drift landings, 71
Dual training, 77, 92, 104
Dunstable, 27, 301

Earthing, 51
Elevators, 59, 62
Elmira, 28
England, Gordon, 16
Espenlaub, G., 28
Evening thermal, 126
Exner, Prof., 12

Fafnir, 219
Falcon, 108, 224, 227
Falcon IV, 94
Flugsport, 18
Fokker, Anthony, 22
Fox, J. S., 133
Fracto-cumulus, 142
Franklin, Prof., 28
Friction, 112, 115
Furness, G. C., 302

Geological influences, 212
Georgii, Dr., 24, 117, 126
Glue, 272
Gradient wind, 112, 159
Groenhoff, G., 28
Grunau IIb, 94, 173, 230
Ground engineer, 102
Ground slides, 60
Groups, 106
Gull, 230
Gull IV, 94, 231
Gust, 114

Hand launching, 37
Hangars, 97
Hankin, Dr., 12
Hardwick, C. E., 117
Harth, F., 17
Hartside, 200
Hekking, R., 17
Helm wind, 200
Hentzen, F. H., 20, 21
Herring, A. M., 14
Hesselbach, P., 27
High-tensile steel, 271
Hill sites, 89, 115
Hirchberg, 29
Hirth, W., 28
Hjordis, 177, 249, 278
Horseley, T., 200
Huish, 308
Humidity, 130, 133

Icing, 208
Income, 103
Inkpen, 309
Instructor, 54, 99
Instrument flying, 73
Instruments, 56, 176, 194, 285
Insurance, 102
Inversion, 123

Jachtmann, E., 22
Jigs, 273

Katabatic wind, 126
Kegel, Max, 25
Kimelman, B., 30
Kirby Kite, 94, 188
Kite II, 231
Kiting, 44
Klenperet, O., 20
Klepikova, O., 29
Koktebel, 27
Kranich, 94, 236
Kress, W., 16
Kronfeld, R., 25, 27

Lanchester, F. W., 17
Landing, 82
Lange, K., 126, 153
Langley, S. P., 14
Lapse rate, 121, 129
Le Bris, J. M., 12
Lenticular cloud, 155, 157
Leonardo da Vinci, 11
Lilienthal, Otto, 13
Lingford, K., 188
Lippisch, A., 24
Long Mynd, 206, 303
London Gliding Club, 27
Löre, 219

Mammato-cumulus, 151
Maneyrol, A., 22
Martens, A., 20
Maxim, Hiram, 16
Mclean, N., 200
Meise, 220
Messerschmidt, W., 18
Midland Club, 303
Mild steel, 270
Minimoa, 175, 183, 220, 234
Montgomery, Prof., 17
Moseley, H. N., 11
Mouillard, P., 11
Mü 13, 187

Nehring, I., 24
Newcastle G.C., 200, 304
Nimbo-stratus, 157
North Downs, 304

Occlusion, 166, 169
Olley, G. P., 22
Olympia, 94
Oolitic limestone, 216
Optimum flying speeds, 183
Oxford G.C., 307
Oxygen, 211

Peschkes, 20
Petterssen, S., 146
Pilcher, Percy, 14
Plywood, 268
Polar air, 160, 164, 172
Portsmouth G.C., 306
Poulter, R. M., 146
Primary, 221
Pringle, J. W. S., 128
Private owners, 109
Professor, 219
Prüfling, 24, 224
Pulleys, 45

Quick releases, 37

Rayleigh, Lord, 12, 17
Raynham, F. P., 22
Releases, 48, 294
Repairs, 281
Retrieving, 94, 186, 298
Rhön mountains, 18
Rhön-Rossiten-Gesellschaft, 24
Rhonadler, 249
Rhonsperber, 286
Rossiten, 23
Rudder, 59

Savtzov, 30
Schweizer SGS-2-8...94, 237
Schreiber, H., 30

Schultz, F , 23
Scud, 164
Sea breeze, 215
S G 38 93
Sideslips, 68, 83
Signals, 49
Sites, 88
Skid, 259
Slatter, A C , 31
Slingsby, 203, 222
Slope lift, 115, 119
Southdown G C , 306
Spins, 70
Spoilers, 47, 84
Sproule, J S , 244
Spruce, 269
Stability (aircraft), 174
Stability, 119, 122
Stalling, 70, 81
Standing waves, 128, 199
Stephenson, G H , 29, 231
Storm collar, 167
Surrey G C , 304
Sutton Bank, 310

Temperature, 119
Thermals, 49, 122, 142, 181
Thunder storms, 218
Tools, 273
Trailer Park, 97
Trailers, 187, 295
Turbulence, 113, 124
Turn and bank, 194, 288
Turns, 66, 72, 80, 82
Tutor, 94, 108

Ulster G C , 311
Ursinus, Oskav, 18
Utility, 94, 108, 230

Vampyr, 20, 219
Variometer, 285
Viking, 278

Walker, Sir G , 144
Warm front, 167
Warm sector, 167
Wasserkuppe, 21, 23, 28
Waves, 128
Weak links, 48
Weihe, 206, 220, 239
Wein, 219
Weiss, J , 16
Wenk, 19
Westpreussen, 219
Wills, P A , 29, 215
Winch, 40, 85, 95, 289
Wind, 111, 139
Wind shadow, 117, 139, 215
Wing section, 251
Wing loading, 252, 254
Wren, 244
Wright Brothers, 15, 17

Yorkshire Gliding Club, 310

Ziller, E , 29, 236
Zogling, 24, 222